UNIVERSITY OF CALICUT

Abstract

General and Academic IV - Faculty of Science - Scheme and syllabus of M.Sc Physics (Nanoscience) programme (CCSS) , in accordance with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024), w.e.f 2024 admission onwards -Approved- Orders Issued

G & A - IV - J

U.O.No. 13027/2024/Admn — Dated, Calicut University.P.O, 23.08.2024

Read:-1. .UO No.3459/2024/Admn dated 27.02.2024
2. Minutes of the online meeting of the Board of Studies in Nanoscience and Technology held on the 17/05/2024
3. Remarks of the Dean, Faculty of Science dated 05/07/2024.
4. Orders of the Vice Chancellor in the file of even No and dated 11/07/2024.

ORDER

1. The Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024) were implemented w.e.f 2024 admission onwards, vide paper read as (1) above.
2. The Board of Studies in Nanoscience and Technology in the meeting held on 17/05/2024, vide paper read as (2), has approved the Scheme and Syllabus of M.Sc Physics(Nanoscience) (CCSS) Programme in tune with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024), w.e.f 2024 admission onwards.
3. The Dean, Faculty of Science vide paper read as (3), has approved the above recommendation of the Board of Studies in Nanoscience and Technology.
4. Considering the urgency, the Vice Chancellor has approved the minutes of the meeting of Board of Studies in Nanoscience and Technology held on 17/05/2024 and accorded sanction to implement the Scheme and Syllabus of M.Sc Physics (Nanoscience) (CCSS) Programme in tune with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024), w.e.f 2024 admission onwards, exercising the powers as per clause 10(13) of Calicut University Act 1975 .
5. The Scheme and Syllabus of M.Sc Physics (Nanoscience) (CCSS) Programme in tune with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024), is therefore implemented w.e.f 2024 admission onwards.
6. Orders are issued accordingly. (Syllabus appended)

Ajayakumar T.K

Assistant Registrar

To

Head, Department of Nanoscience and Technology, University of Calicut,
Copy to: Copy to:Copy to: PS to VC/PA to PVC/ PA to Registrar/PA to CE/JCE I/JCE V/JCE VIII/DoA/EX and EG Sections/GA I F/ DOA/CHMK Library/SUVEGA/SF/DF/FC

Forwarded / By Order

Section Officer

DEPARTMENT OF NANOSCIENCE AND TECHNOLOGY

Programme:

1. **M.Sc. PHYSICS (NANOSCIENCE)**
   Program Code: **FSCNSPHMSC**

SCHEME, CURRICULUM & SYLLABUS

UNIVERSITY OF CALICUT

(A State University Accredited with "A^{+}" Grade by NAAC)

Calicut University P.O., Kerala, 673635, INDIA
Ph: 0494 2407373, 2407374, *Email*: nanohod@uoc.ac.in
www.universityofcalicut.info, https://nanotechnology.uoc.ac.in

MAY 2024

Scheme and Syllabus for

M.Sc. Physics (Nanoscience) (Code: FSCNSPHMSC)

Under (CCSS-PG-2024)

Department of Nanoscience and Technology, School of Physical Sciences,

University of Calicut, (w.e.f. 2024 admission onwards)

ELIGIBILITY FOR ADMISSION

B.Sc. Degree in Physics of this university or an equivalent degree, with Mathematics and Chemistry as compulsory complementary, having 50% marks or equivalent grade in Part III (Core and complementary put together) are eligible to apply for this programme. OBC/OEC candidates are eligible for relaxation up to 5%. SC/ST candidates need only to get a pass.

ADMISSION PROCEDURE

Admission to this MSc program shall be based on entrance examination conducted among eligible candidates and successful candidates shall be ranked according to the entrance test marks. Program structure, evaluation and grading will be as per the Choice-based Credit Semester System PG - CCSS Regulations for Post Graduate Programmes of Teaching Departments/Schools of the University of Calicut. Intake is 10.

SCHEME AND CURRICULUM OF THE PROGRAM

- M.Sc. Physics (Nanoscience) is a PG program of 2 years duration with 4 semesters. The program includes Core, Elective and MOOC courses. The total credit of the program is **88**.
- Total credits for the core courses (Theory, Practical) shall be **36**.
- The Project work is compulsory for all students and the credit points assigned is **20.**
- Total credits for the elective courses shall be **20**
- Total credits for the MOOC courses shall be **12**
- Minimum credits required from core courses (Theory, Practical, Project) is **56**
- Minimum credits required from elective courses is **20**
- Minimum credits for the MOOC courses shall be **12**
- Accumulated minimum credits required for successful completion of the program is **88**
- Minimum attendance required is **75 %**
- **Evaluation and grading will be done as per CCSS PG Regulations 2024 - Regulations for Post Graduate Programmes of Teaching Departments/Schools of the University of Calicut**

Program Specific Outcomes (PSOs)

The PG programme, **M.Sc. Physics (Nanoscience)** offers a well-balanced curriculum that ensures the career prospects of the students with due consideration is given to capacitate the students to face the challenges posed by the specialized areas of knowledge in the global arena. Since Nanoscience being an applied science and has application in various fields, in other words, being a vastly interdisciplinary area with great fluidity, the competence of the students can be improved with specialization and focus on chosen areas.

PSO-1	Recognise and relate the theories and principles of solid state and quantum physics to understand scientific phenomenon in the nanoscale domain.
PSO-2	Acquire skills in advanced experimental and theoretical methods for measurement, observation, and fundamental understanding of phenomena at the nanoscale.
PSO-3	Develop proficiency in using modern instrumentation and techniques essential for nanoscience research.
PSO-4	Cultivate strong communication skills to effectively disseminate knowledge to both scientific and non-scientific audiences.
PSO-6	Encourage continuous learning and staying updated with the latest advancements in nanoscience and nanotechnology.
PSO-7	Understand and apply safety protocols and regulations in the handling and experimentation of nanomaterials.
PSO-8	Enhance critical thinking and analytical skills for innovative research and development in nanoscience.
PSO-9	Provide opportunities for industry collaborations and internships to bridge the gap between academia and industry.
PSO-10	Foster an entrepreneurial mindset to explore the commercialization of nanotechnology-based innovations.
PSO-11	Promote the development of novel nanotechnological applications in healthcare, electronics, and environmental science.
PSO-12	Understand the global landscape of nanotechnology research and its economic and geopolitical implications.

University of Calicut, Kerala- 673635

M.Sc. Physics (Nanoscience)

Course and Credit Distribution Summary (2024 admission onwards)

Semester	Course Code	Subject	Type	Total Marks	Credits
First Semester (500 Level)	NSP7C 501	Classical Mechanics	DSC(A) 1	100	4
	NSP7C 502	Electronics	DSC(A) 2	100	4(3+1)
	NSP7C 503	Mathematical Physics	DSC(A) 3	100	4
	NSP7E 501	Physics and Chemistry of Solids	DSE(A) 1	100	4 (3+1)
	NSP7E 502	Structure and Properties of Materials	DSE(A) 1	100	4
	NSP7E 503	Surface Energy and Growth Kinetics of Nanomaterials	DSE(A) 1	100	4 (3+1)
	NSP7E 504	Everyday Materials: Understanding Their Science and Impact	DSE(A)2 OE	100	4
	NSP7E 505	Physics in Everyday Life	DSE(A)2 OE	100	4
	NSP7M 501	MOOC -I	Online	100	4
		TOTAL CREDITS			**24**
Second Semester (500 Level)	NSP8C 504	Statistical Mechanics	DSC(A) 4	100	4 (3+1)
	NSP8C 505	Electrodynamics	DSC(A) 5	100	4 (3+1)
	NSP8C 506	Quantum Mechanics -I	DSC(A) 6	100	4 (3+1)
	NSP8E 506	Precision Nanoclusters: Origin and Applications	DSE(A) 3	100	4 (3+1)
	NSP8E 507	Nanostructured Solar Cells	DSE(A) 3	100	4
	NSP8E 508	Solid State Physics of Materials	DSE(A) 3	100	4
	NSP8M 502	MOOC -II	Online	100	4
		TOTAL CREDITS			**20**
Third Semester (600 Level)	NSP9C 601	Nuclear and Particle Physics	DSC(A) 7	100	4
	NSP9C 602	Quantum Mechanics -II	DSC(A) 8	100	4 (3+1)
	NSP9C 603	Molecular Spectroscopy	DSC(A) 9	100	4 (3+1)
	NSP9E 601	Advanced Analytical Techniques	DSE(A) 4	100	4
	NSP9E 602	Micro/Nano Electro-mechanical Systems (MEMS/NEMS)	DSE(A) 4	100	4
	NSP9E 603	Computational Nanotechnology	DSE(A) 5	100	4 (3+1)
	NSP9E 604	Design, Synthesis and Properties of Nanomaterials	DSE(A) 5	100	4 (3+1)
		TOTAL CREDITS			**20**

Fourth Semester **(600 Level)**	NSP10P 601	Project	Project	100	20
	NSP10M 601	MOOC -III	Online	100	4
		TOTAL CREDITS			**24**
		Project OR 5 Core papers with total 20 credits (Applicable for FYUG – PG students)			
	NSP10C 604	Bio-Nanomaterials	DSC(A) 10	100	4
	NSP10C 605	Advanced Nanomaterials	DSC(A) 11	100	4
	NSP10C 606	Nanostructured Super Capacitors	DSC(A) 12	100	4
	NSP10C 607	Nanomaterials for Sustainable Technology	DSC(A) 13	100	4
	NSP10C 608	Computational Studies on Bio-active Compounds	DSC(A) 14	100	4
		TOTAL CREDITS			**20**
		TOTAL CREDITS (I, II, III and IV Sem.) : 88			

EVALUATION AND GRADING: As per the Calicut University Regulations under Choice Based Credit Semester System for Postgraduate Programmes (CCSS-PG) of the University Campus Departments.

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PATTERN OF QUESTION PAPER FOR CORE AND ELECTIVE COURSES:

M.Sc. Physics (Nanoscience)

Time: 3 hours **Total Marks = 50**

Section A

Ten Compulsory short answer type questions of one mark each
(Total Marks = 10 **x 1=10 Marks)**

Section B

Eight paragraph answer type questions, the students shall answer 4 question each of four marks **(**Total Marks **= 4 x 4 = 16 marks)**

Section C

Eight essay/problem type questions, the students shall answer four questions, each of six marks
(Total Marks = **4 x 6=24 marks**)

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SYLLABUS

M.Sc. Physics (Nanoscience)
(Code: FSCNSPHMSC)

Discipline Specific Courses
DSC (A)
&
Discipline Specific Electives
DSE (A)
&
MOOC – Online Courses

<table>
<tr><td>Course Code</td><td>NSP7C 501</td><td rowspan="2">CLASSICAL MECHANICS</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Core</td><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge in general physics</td><td>Syllabus Version</td><td colspan="3">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
<tr><td colspan="7">Course Objectives</td></tr>
<tr><td colspan="7">The main objectives of the course are to:
• Understand the fundamental concepts and principles in of classical physics.
• Learn different theorems and the associated mathematical derivations.
• Understand the dynamics of different systems.
• Learn and develop mathematical skills applied to physics.</td></tr>
<tr><td colspan="7">Course Outcomes</td></tr>
<tr><td colspan="7">1. Remember the fundamentals of classical mechanics – K1
2. Able to solve the motion of a mechanical system using Lagrange and Hamiltonian formulations – K2
3. Solve problems associated with rigid body motion– K5
4. Explain the types of different motions of linear and non-linear oscillations – K1</td></tr>
<tr><td colspan="7">K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate</td></tr>
<tr><td>UNIT-I</td><td colspan="3">Lagrangian Formulations</td><td colspan="3">12 Hours</td></tr>
<tr><td colspan="7">D'Alemberts principle and Lagrange's equation, Velocity dependent potentials, Simple applications of Lagrangian formulation, Hamilton's Principle, Conservation theorems and symmetries, Lagrange's equation from Hamilton's principle, Two- body central force problems, Equivalent one - body and one-dimensional problem, Kepler problem, Inverse square law of force, Laplace-Lenz vector, Scattering in a central force field, Transformation to lab coordinates.</td></tr>
<tr><td>UNIT-II</td><td colspan="3">Hamiltonian Formulations</td><td colspan="3">14 hours</td></tr>
<tr><td colspan="7">Legendre Transformation and Hamilton's equations, Cyclic co-ordinates and conservation theorems, Principle of least action, Canonical transformations and examples, Infinitesimal canonical transformations, Poisson brackets and other canonical invariants, Equation of motion in Poisson bracket form, Angular momentum Poisson brackets. Hamilton-Jacobi equation, Hamilton's principal and characteristic function, H-J equation for the linear harmonic oscillator, Separation of variables, Action-angle variables, H-J formulation of the Kepler problem, H-J equation and the Schrodinger equation.</td></tr>
<tr><td>UNIT-III</td><td colspan="3">Kinematics of Rigid Body Motion</td><td colspan="3">12 Hours</td></tr>
<tr><td colspan="7">Independent co-ordinates, orthogonal transformation, Transformation matrix, Euler angles, Euler theorem, Infinitesimal rotation, Rate of change of a vector, Centrifugal and Coriolis forces, Inertia tensor, Euler's equation of motion, Torque-free motion of a rigid body, Precession of Equinoxes and satellite orbits.</td></tr>
<tr><td>UNIT-IV</td><td colspan="3">Small Oscillations</td><td colspan="3">12 Hours</td></tr>
</table>

Formulation of the problem, Eigenvalue equation, Eigenvectors and Eigenvalues, Orthogonality, Principal axis transformation, Frequencies of free vibrations, Normal coordinates, Free vibrations of a linear triatomic molecule, Forced vibration and Dissipative forces.		
UNIT-V	**Nonlinear Equations and Chaos**	**10 Hours**
Introduction, Singular points of trajectories, Nonlinear oscillations, Limit cycles, Chaos: Logistic map, Definitions, Fixed points, Period doubling, Universality.		
	Total Lecture Hours	**60 Hours**
Text Books/References		

Text Books:

1. Herbert Goldstein, Charles P.Poole and John Safko : "Classical Mechanics" (3rd Edition, Pearson Education,2011)
2. V.B.Bhatia : "Classical Mechanics" (Narosa Publications,1997)

Books for Reference:

1. Michael Tabor: "Chaos and Integrability in Nonlinear Dynamics" (Wiley,1989)
2. N.C.Rana and P.S.Joag : "Classical Mechanics" (Tata McGraw Hill,2011)
3. R.G.Takwale and P.S.Puranik : "Introduction to Classical Mechanics"(Tata McGraw Hill, 1978)
4. Atam P. Arya, Introduction to Classical Mechanics, 2nd Edn.,Addison Wesley,1998)
5. Muthusamy Lakshmanan, Shanmuganathan Rajaseekar : "Nonlinear Dynamics" (Springer Verlag,2002).

Course Code	NSP7C 502	ELECTRONICS	L	T	P	C
Core			**3**	**0**	**1**	**4**
Pre-requisite	Basic knowledge in general physics and basic electronics		**Syllabus Version**		**2024**	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- To understand bi-junction uni-junction transistor amplifiers and their frequency performances and applications.
- To understand the architecture and performance of various semiconductor components for microwave and photonic devices
- To understand the architecture and working of an Op-Amp and its characteristics and equivalent circuit
- To understand the practical applications of an Op-Amp

Course Outcomes

1. Analyze the performance and differentiate voltage and current amplifiers and design a public address system - K5
2. Analyze the frequency response, input and output impedances of various Op-Amp based circuits for practical applications – K4
3. Analyze arithmetic logic circuits, and apply the knowledge to explain the working of various counters and registers - K4
4. Design a microprocessor-based circuit for practical applications- K5

K1– Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate

UNIT-I	Field Emission Transistors	10 Hours

BJT: Biasing and ac models, Voltage amplifiers, Power amplifiers, Emitter follower. FET: h-parameters, FET small signal model, Biasing FET, Analysis of common source and common drain amplifiers at low and high frequencies, FET as VVR and its applications. MOSFET: Circuit symbol and equations, small signal model, CMOS and Digital MOSFET gates.

UNIT-II	Digital Electronics	12 hours

Combinational systems - Synthesis of Boolean functions, Boolean algebra, Universal gate - NAND, Integrated NAND circuit, Arithmetic circuits, Adder, Subtractor, BCD Addition, 2's complementary technique, Sequential systems - Flip flops-RS, JK, JK-MS, D-FF, Register, Buffer register, serial and parallel registers, Tristate switches, Tristated buffer registers, Bus organisation in computers, Counters, Synchronous and Asynchronous counters, Ripple counters, Ring counter, Timing diagram, Fundamentals of D/A conversion, -Accuracy and resolution - ADC/DAC chips, Flash Converters

UNIT-III	Operational Amplifier (OPAMP)	13 Hours

Ideal amplifier - operational amplifier - the basic operational amplifier, differential amplifier and its transfer characteristics, frequency response of operational amplifiers, adder, subtractor, Solution of differential equations – general ideas about analog computation and

simulation, Filters, Comparators, sample and hold circuits, Opamp applications: Summing, scaling and averaging amplifiers, Op-amp as differentiators, integrators, applications of differentiators and integrators, Active filters: Low pass, High pass, Band pass, Butterworth filters, Oscillators: Phase shift, Wein bridge, Quadrature oscillators, Waveform generators: Square, triangular and saw-tooth wave generators, comparators as zero crossing detectors, Schmitt trigger.		
UNIT-IV	**Applications of Electronic Devices in Materials Science**	**10 Hours**
Tunnel diode, Transferred electron devices, Negative differential resistance and devise operation, Radiative transitions and optical absorption, Light emitting diodes (LED) – Visible and IR, Semiconductor lasers - materials, operation (population inversion, carrier and optical confinement, optical cavity and feedback, threshold current density), Photo-detectors, Photoconductor (Light dependent resistor- LDR) and photodiode, p-n junction solar cells - short circuit current, fill factor and efficiency.		
UNIT-V	**Practical Experiments**	**30 hours**
1. Inverting Amplifier, Non-inverting Amplifier and Difference Amplifier 2. Schmitt Trigger, 3. Sawtooth Generator, 4. Differentiator and Integrator, 5. Low pass filter, High pass filter and Band pass filter, 6. Astable Multivibrator 7. Single stage RC coupled Amplifier, 8. Differential Amplifier using Transistor, 9. Logic gates, 10. FET characteristics, 11. Darlington pair Amplifier, 12. Semiconductor characteristics		
TOTAL lecture + Practical hours: 75 Hours		
Text Books/References		

1. Malvino, "Electronic Principles" 6th Edition, TMH India
2. R. A. Gayakwad : "Op-Amps and Linear Integrated Circuits"(3rd Edition, PHI)
3. Leach, Malvino and Saha : "Digital Principles and Applications" 6th Edition, TMH.
4. Ramesh S. Gaonkar: "Microprocessor Architecture, Programming and Applications with the 8085", New Age Publishers.
5. The 8051 Microcontroller: 2nd Edition, Kenneth J. Ayala, Thomson, Delmar Learning.
6. John Ryder, Electronic Fundamentals and Applications (5th Edition), Prentice Hall, New Delhi, (1983).
7. Milman and Halkias, Integrated Electronics, Mc. Graw Hill, (1983).
8. Robert G. Irvine, Operational Amplifier – Characteristics and Applications, 2nd Edition, Prentice Hall, New Jersey (1987).
9. Gaonkar, Microprocessor Architecture, Programming and Applications, Wiley Eastern Limited, New Delhi (1992).
10. John Wakerly, Digital Design: Principles and Practices (4th Ed.), Prentice Hall (2005).
11. D. C. Green, Digital Electronics (5th Ed.), Pearson Education Ltd., (2005).
12. Roddy and Coolen, Electronic Communications, Prentice Hall 4th Ed (1995).
13. B. P. Lathi, Modern Digital and Analog Communication Systems 3rd Ed, Oxford University press (1998).
14. S. M. Sze.,"Semiconductor Devices- Physics and Technology" (John Wiley and Sons.

Course Code	NSP7C 503	MATHEMATICAL PHYSICS	L	T	P	C
Core			4	0	0	4
Pre-requisite	Basic knowledge in Mathematics and Physics		Syllabus Version	2024		

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- Understand the fundamentals of Mathematical Physics
- Recognize mathematics as the language of nature to explain different physical phenomena
- Understand the use of Physics to address the fundamental questions in nature.
- To understand the applications of Mathematical tools for solving physical problems

Course Outcomes

1. Understand different coordinate systems and apply the same to solve Laplace's equation- K2, K3
2. Identify tensors, their classifications and application -K2
3. Recognize differential equations of special nature and analyse their solutions to address atomic, molecular and solid-state physics -K2,K4
4. Apply Fourier series and integral transforms of different types to analyse or solve mathematical problems in physical sciences-K3

K1- Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate

UNIT-I	Vector and matrix analysis	12 Hours

Vectors algebra and calculus, gradient, divergence and curl, Rotation of coordinates, Orthogonal curvilinear coordinates, Gradient, Divergence and Curl in orthogonal curvilinear coordinates, Rectangular, cylindrical and spherical polar coordinates, Laplacian operator, Laplace's Equation-Vector integration and integral theorems. Basic properties of matrices(review), Orthogonal matrices, Hermitian and Unitary matrices, Similarity and unitary transformations, Diagonalization of matrices.

UNIT-II	Tensors analysis and group theory	14 hours

Definition of Tensors, Contravariant and covariant tensors – transformation rules – direct product, contraction, quotient rule. Metric tensor – lowering and raising of indices – covariant derivatives – Christoffel symbols. Introductory group theory, group multiplication table, Homomorphism and Isomorphism, reducible and irreducible representations, Schur's Lemmas and great orthogonality theorem

UNIT-III	Second Order Differential Equations & Special functions	14 Hours

Partial differential equations, first order equation, second order equation, Separation of variables, Laplace and poisson equation, wave and heat equations in two and three dimensions.

Gamma and Beta functions and its properties. Frobenius method for solving second order

ordinary differential equations with variable coefficients. Bessel, Legendre, Hermite and Laguerre equations. Recurrence relations, Generating functions and Rodrigues formulae for the Bessel, Legendre Hermite and Laguerre functions. Green's function.		
UNIT-IV	**Functions of Complex Variables**	**10 Hours**
Introduction, Analyticity, Cauchy-Reimann conditions, Cauchy's integral theorem and integral formula, Laurent expansion, Singularities, Calculus of residues and applications. Calculus of Variations, Euler equation, variation with constraints.		
UNIT-V	**Integral Transforms**	**10 Hours**
Fourier Series, General properties, Advantages, Uses of Fourier series, Properties of Fourier series, Fourier integral, Fourier transform, Properties, Inverse transform, Transform of the derivative, Convolution theorem, Laplace transform, Inverse Transform and Convolution theorem.		
	Total Lecture Hours	**60 Hours**

Text Books/References

1. Tai L.Chow, Mathematical Methods for Physicists
2. G.B.Arfken and H.J.Weber : "Mathematical Methods for Physicists"(6th Edition, Academic Press,2005)

Books for Reference:

1. J.Mathews and R.Walker, "Mathematical Methods for Physics" (2nd Edition)
2. L.I.Pipes and L.R.Harvill, "Applied Mathematics for Engineers&Physicists"(3rd Edition,McGrawHill)
3. Erwin Kreyzig : "Advanced Engineering Mathematics"(8th edition, Wiley)
4. M. Greenberg, "Advanced Engineering Mathematics" (2nd Ed., Pearson India, 2002)
5. A.W. Joshi, "Matrices and tensors in Physics" (New Age International Publishers)
6. Nazrul Islam, "Tensors and Their Applications", (New Age international) 2006
7. "Elements of group theory for Physicists" (New Age International Publishers),

Course Code	NSP7E 501	PHYSICS AND CHEMISTRY OF SOLIDS	L	T	P	C
Elective			3	0	1	4
Pre-requisite	Basic knowledge in crystals and solids		Syllabus Version	2024		
L= Lecture, T= Tutorial, P- Practical, C= Credits						

Course Objectives		
The main objectives of the course are to: • Understand the fundamental concepts and principles of material science. • Learn the method of solving problems mathematically. • Understand the concepts and theories describing the properties of solid state materials. • Apply the knowledge to manipulate the working of solid state electronic devices.		
Course Outcomes		
1. Identify crystallographic features and apply X-ray diffraction techniques for structure analysis (K2, K3) 2. Analyze crystal packing, defects, and electronic properties, calculating carrier concentration and Fermi level in semiconductors (K4) 3. Interpret electronic, dielectric, and thermal properties of solids (K4) 4. Analyze the behaviour of different solids by evaluating the fundamental theories (K4, K5)		
K1– Remember, K2 – Understand, K3 – Apply, K4 – Analyze, K5 – Evaluate		
UNIT-I	**Crystalline State**	**10 Hours**
Crystal morphology: symmetry elements, crystal systems; Bravais lattices; Crystal planes and directions: Miller indices, interplanar separations. Crystal symmetry, Symmetry elements and symmetry operations. Structure analysis by X-rays: Atomic scattering factor; Laue conditions for diffraction and Bragg's law; Powder X-ray diffraction.		
UNIT-II	**Crystal Packing, Defects and Theories**	**10 hours**
Packing in a crystal: BCC, FCC, HCP structures with examples, Point defects, line defects, plane defects. Free electron theory of metals, Band theory of solids, Effective mass; Direct and Indirect bandgaps: Determination of bandgap; Donors and acceptors, carrier concentration at thermal equilibrium; Calculation of Fermi level; Degenerate and Non-degenerate semiconductors.		
UNIT-III	**Electronic and Dielectric Properties**	**13 Hours**
Free electron gas in three dimensions, heat capacity of electron gas, electrical conductivity and Ohm's law, Experimental electrical resistivity of metals, Motion in magnetic fields, Hall effect, Thermal conductivity of metals (Wiedemann-Franz law), Nearly free electron model-origin of energy bands, Magnitude of energy gap, Bloch functions, Kronig Penny model, Semiconductor crystals: band gap, direct/indirect bad gap SCs, Equation of motion, Holes, Effective masses in semiconductors, Intrinsic carrier concentration, Impurity conductivity, Thermoelectric effects. Theory of Dielectrics: Polarisation, Dielectric constant, Local Electric field, Dielectric polarisability, Clausius- Mossotti relation, Polarisation from dipole orientation, Dielectric losses, Ferroelectric crystals, Order-disorder type ferroelectrics, Polarisation catastrophe, Displacive type ferroelectrics, Landau theory of ferroelectric phase transitions, Ferroelectric domain, Antiferroelectricity, Piezoelectricity, Applications of Piezoelectric Crystals.		
UNIT-IV	**Magnetic Properties**	**12 Hours**

Diamagnetism and Paramagnetism: Langevin's diamagnetism equation, Quantum theory of diamagnetism of mononuclear systems, Quantum theory of paramagnetism, Hund's rule, Paramagnetic susceptibility of conduction electrons, Ferro, Anti and Ferri magnetism: Curie point and the exchange integral, Magnons, Ferrimagnetic order, Curie temperature and susceptibility of ferrimagnets, Antiferromagnetic order. Weiss theory of ferromagnetism, Ferromagnetic domains, Bloch walls, Origin of domains.

UNIT-V	**Practical Experiments**	**30 Hours**

1. Study of energy band gap and diffusion potential of P-N junction.
2. Determination of Particle size of Lycopodium powder using He-Ne laser.
3. Temperature Dependence of Hall coefficient. Determination of Carrier concentration and mobility.
4. Determination of band gap of a semiconductor by four probe method.
5. Solar Power and I-V characteristics of semiconductor thin films.
6. Determination of concentration of an unknown solution through UV-Vis spectrophotometer: Verification of Beer-Lambert Law.
7. Analysis of crystal structure of a given sample using its XRD data.

Total Lecture + Practical Hours : 75 Hours

Text Books/References

1. D.A McQuarrie and J.D. Simon, Physical Chemistry, a molecular approach, University Science Books.
2. Tareen and Kutty, Solid state chemistry.
3. Lesley Smart & Elaine Moore, SolidState Chemistry, nelson Thornes.
4. A.K. Galway, Chemistry of Solids, Science Paperbacks and Chapman and Hall Ltd., London 91967).
5. A.R. West, basic Solid State Chemsitry, John Wiley & Sons Ltd. (1991).
6. B.S.Skoog and D.M. West, Principles of Instrumental Analysis, Sanndes College, Philadelphia (1980).
7. Atomic structure and chemical Bond, Manas Chanta **Publisher:** McGraw-Hill Inc.,US (1 December 1974) **ISBN-10:** 0070965110
8. Concise Inorganic chemistry, J.D.Lee **Publisher:** Wiley; 5th edition edition (18 December 1998) **ISBN-10:** 0632052937
9. Inorganic Chemistry, G. Wwfsberg Unit IV **Publisher:** Pearson; 4 edition (31 May 2012) **ISBN-10:** 0273742752
10. Introduction to solids – L.V. Azaroff **Publisher:** McGraw Hill Education; New edition edition (14 June 2001) **ISBN-10:** 0070992193
11. Introduction to solid state Physics – C. Kittel **Publisher:** John Wiley & Sons Inc (23 July 1996) **ISBN-10:** 0471142867
12. Elements of solids state physics, J.P. Srivastava **Publisher:** Prentice Hall India Learning Private Limited; 4th Revised edition edition (17 December 2014) **ISBN-10:** 8120350669
13. Superconductivity and Superconducting Materials – A V Narlikar and S N Ekbote (South Asian Pub., 1983).
14. Physics of high Tc superconductors – J C Phillips (Academic Press, 1989)
15. Introduction to superconductivity – A C Rose-Innes and E H Rhoderick (Pergamon Press, 1978)

<table>
<tr><td>Course Code</td><td>NSP7E 502</td><td rowspan="2">STRUCTURE AND PROPERTIES OF MATERIALS</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Elective</td><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Fundamentals of Physics and Chemistry at Undergraduate level</td><td>Syllabus Version</td><td colspan="3">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
<tr><td colspan="7">Course Objectives</td></tr>
<tr><td colspan="7">1. Understand the fundamental principles governing the structure and properties of materials.
2. Explore the principles of metallurgy and phase transformations in materials.
3. Examine the physics of semiconductors and their practical applications.
4. Analyze the mechanical, optical, and magnetic properties of materials.</td></tr>
<tr><td colspan="7">Course Outcomes</td></tr>
<tr><td colspan="7">1. Understand the atomic structure of materials, imperfections in solids, and apply microscopic techniques for material characterization (K2, K3)
2. Analyze phase transformations in materials and interpret phase diagrams (K3, K4)
3. Apply principles of semiconductor physics and evaluate diffusion processes in solids for industrial applications (K3, K5)
4. Analyze mechanical properties and comprehend the optical and magnetic properties</td></tr>
<tr><td colspan="7">K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create</td></tr>
<tr><td>UNIT-I</td><td colspan="3">Structure of Materials</td><td colspan="3">12 hours</td></tr>
<tr><td colspan="7">Introduction and structure of materials, why study properties of materials? Structure of atoms - Quantum states-Atomic bonding in solids-binding energy-interatomic spacing - variation in bonding characteristics - Single crystals – polycrystalline - Non crystalline solids - Imperfection in solids – Vacancies – Interstitials - Geometry of dislocation - Schmid´s law - Surface imperfection - Importance of defects - Microscopic techniques - grain size distribution</td></tr>
<tr><td>UNIT-II</td><td colspan="3">Metallurgy and Phase Transformations</td><td colspan="3">14 hours</td></tr>
<tr><td colspan="7">Solidification of Metals - Solidification of Single Crystals - Metallic Solid Solutions - Rate Processes in Solids - Diffusion in Solids, Industrial Applications of Diffusion Processes - Effect of Temperature on Diffusion in Solids - Phase diagrams - Gibbs phase rule - Single component systems – Eutectic phase diagram – lever rule - Study of properties of phase diagrams - Phase transformation - Nucleation kinetics and growth</td></tr>
<tr><td>UNIT-III</td><td colspan="3">Physics of Semiconductors</td><td colspan="3">12 hours</td></tr>
<tr><td colspan="7">Band model of semiconductors - carrier concentrations in intrinsic, extrinsic semiconductors – organic semiconductors - Fermi level - variation of conductivity, mobility with temperature – law of mass action - Hall effect - Hall coefficients for intrinsic and extrinsic semiconductors – Hall effect devices. Application of diffusion in sintering, doping of semiconductors and surface hardening of metals.</td></tr>
</table>

UNIT-IV	Mechanical Properties of Materials	12 hours
Mechanical Properties of Metals - Processing of Metals and Alloys - Stress and Strain in Metals, The Tensile Test and The Engineering Stress-Strain Diagram, Hardness and Hardness Testing, Plastic Deformation of Metal Single Crystals, Plastic Deformation of Polycrystalline Metals - Solid-Solution Strengthening of Metals, Recovery and Recrystallization of Plastically Deformed. Metals, Fracture of Metals - Fatigue of Metals - Creep and Stress Rupture of Metals. Tribology: wear of metals - mechanisms, factors influencing wear, wear resistance - protection against wear.		
UNIT-V	**Optical and Magnetic Properties of Materials**	**10 Hours**
Optical properties - Light interaction with solids - Atomic, electronic interaction, non – radiative transition - refraction, reflection, Absorption, Transmission, Insulators, luminescence. Magnetic properties - paramagnetism - ferromagnetism - domain theory - magnetic hysteresis, Weiss molecular field theory, Heisenberg's theory - magnetic anisotropy - domain walls - Exchange energy –antiferromagnetism		
	Total Lecture Hours	**60 Hours**
Text Books/References		

Text Books:

1. Materials Science and Engineering-An Introduction 7e, William D. Callister, (Wiley, 2007).
2. K. Vijayamohanan Pillai and Meera Parthasarathi Functional Materials: A Chemist’s Perspective by, Orient Blackswan (21 November 2013).
3. C. Kittel, "Introduction to Solid State Physics" Wiley Eastern Ltd, 2005.
4. V. Raghavan, “Materials Science and Engineering: A First Course", Prentice Hall, 2006.
5. A.J. Dekker, "Solid State Physics”, Macmillan & Co, 2000.
6. Michael Shur, "Physics of Semiconductor Devices", Prentice Hall of India, 1995.
7. Charles P Poole Jr., and Frank J. Ownes, Introduction to Nanotechnology, John Wiley Sons, Inc., 2003.
8. H. S. Nalwa (Ed.), "Encyclopedia of Nanoscience & Nanotechnology", American Scientific Publishers, California, 2004.
9. V.R.Gowariker, “Polymer science “,New age international Publishers, 1986
10. Introduction to magnetic materials, B. D. Cullity, C. D. Graham, Published by John Wiley & Sons, Inc., Hoboken, New Jersey, 2009

<table>
<tr><td>Course Code</td><td>NSP7E 503</td><td rowspan="2">SURFACE ENERGY AND GROWTH KINETICS OF NANOMATERIALS</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Elective</td><td>3</td><td>0</td><td>1</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Fundamentals of Physics and Chemistry at Undergraduate level</td><td colspan="2">Syllabus Version</td><td colspan="2">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
</table>

Course Objectives

1. Recognize the interdisciplinary area of Nanoscience and Technology
2. Realize different nano systems and recognize the advanced tools used for their analysis
3. Understand the reasons behind size dependent physical or chemical properties of nanomaterials
4. Analyze the phase transformation process and understand how to control that process for nanostructure creation
5. Introduce different methods available for the fabrication of nanostructures

Course Outcomes

1. Recognize different nanosystems and the tools for their analysis (K2)
2. Understand the size dependent physical phenomenons observed in nanomaterials (K2)
3. Realize the origin of surface energy, energy minimization and stabilization processes in nanosystems (K2)
4. Understand and apply the kinetics of phase transformation in nanosystems (K2,K3)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Introduction to Nano-systems**	**8 Hours**

Feynmann's vision on nanoscience & technology, bulk vs nanomaterials, natural and synthetic nanomaterials. Quantum confinement in nanostructures- size dependent physical phenomena in semiconductor and metal nanoparticles. Classification of nanostructures, 0D, 1D and 2D nanostructures. Visualization of nanostructures and techniques related.

UNIT-II	**Surface Energy**	**13 Hours**

Surface energy and surface stress-origin and estimation of surface energy. Surface Energy minimization:- Sintering Ostwald ripening and agglomeration. Energy minimization by Isotropic and anisotropic surfaces. Surface energy and surface curvature, Surface energy stabilization- electrostatic stabilization, steric stabilization, electro-steric stabilization..

UNIT-III	**Growth Kinetics of Nanomaterials**	**13 Hours**

Kinetics of phase transformations, Homogeneous & Heterogeneous nucleation. Controlling nucleation, growth and aggregation in nanoparticle growth. Growth Mechanisms: Spontaneous growth, Evaporation condensation growth, growth controlled by diffusion and surface process, VLS growth, fundamentals of thin film growth.

UNIT-IV	Special Nanostructures	11 Hours
Carbon Nanostructures: Fullerenes, CNTs and Graphene- structure and physical properties. Micro & Mesoporous Materials, Ordered mesoporous structures, Random mesoporous structures, and crystalline microporous materials: zeolites. Core – Shell Structures **-** Metal-oxide structures, Metal-polymer structures, Oxide-polymer structures. Organic-Inorganic Hybrids- Class I hybrids, Class II hybrids, Intercalation Compounds.		
UNIT-V	**Practical Experiments**	**30 Hrs**.
1. Synthesis of different sized Ag nanoparticles by aqueous method, Size distribution studies using DLS 2. UV-Vis absorption studies of different sized Ag nanoparticles and calculation of particle size comparing with reported literature 3. Synthesis of different sized Au nanoparticles by aqueous method, Size distribution studies using DLS 4. UV-Vis absorption studies of different sized Au nanoparticles and calculation of particle size comparing with reported literature 5. Green Synthesis of carbon nanodots and their optical characterization 6. Polymer thin film preparation using spin coating method and thickness measurement using Profilometer.		
	Total Lecture + Practical Hours	**75 Hours**
Text Books/References		

Text Books:

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao, Imperial College Press, (2006). (for UNIT I & II, 2nd Chapter, Unit III – Chapter 4 (3.2), Unit IV- Chapter 7
2. Nanomaterials and Nanochemistry by C. Brechignac.P. Houdy M. Lahmani Springer-Verlag (2007). (For Unit III-Part I Chapter I)
3. Materials Science and Engineering-An Introduction 7e, William D. Callister, (Wiley, 2007). (Chapter 10. section 1-.2 and 10.3) Unit II.

Reference:

1. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. **Publisher:** CRC Press (15 December 2008) **ISBN-13:** 978-1420047790
2. Introduction to Nanoscale Science & Technology, Di Ventra, Evoy, Heflin, Springer Science, NY, 2004. **Publisher:** Springer; 1 edition (30 June 2004) **Sold by:** Amazon Asia-Pacific Holdings Private Limited.

Course Code	NSP7E 504	**EVERYDAY MATERIALS: UNDERSTANDING THEIR SCIENCE AND IMPACT**	L	T	P	C
OPEN ELECTIVE			4	0	0	4
Pre-requisite	Basic knowledge in science		**Syllabus Version**		**2024**	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- Understand various materials and their fundamental properties.
- Explore the role of materials in technology and industry.
- Analyze the impact of materials on the society.
- Investigate emerging trends and innovations in materials science.

Course Outcomes

5. Remember how materials are classified – K1
6. Understand the properties of various materials – K2
7. Understand how materials and applied depending on their properties – K2, K3
8. Analyze and evaluate the role of different materials for technological advancements – K4, K5

K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate

UNIT-I	Solid Materials	17 Hours

Solid state materials: Definition, elementary ideas of electrical properties, optical properties, mechanical properties, thermal properties. Specific examples of metals- Copper, Aluminium, Iron, Gold, Silver. Uses of metals. Drawbacks of metals. Alloys: advantages of alloying. Examples-Brass, Bronze, Steel, Stainless steel, Gold alloys, silver alloys and their uses. Semiconductors: Elemental semiconductors- Silicon, Germanium. Doping- n-type and p-type semiconductors, p-n junctions. Qualitative ideas of devices- diodes to ICs. Compound Semiconductors.

UNIT-II	Polymers	15 hours

astics- Introduction. Types of plastics. Rubber- Types of rubber. Vulcanization of rubber. Fibres- Different types of natural and synthetic fibres. Resins, Adhesives and polymer coatings. Physical, chemical, mechanical properties and applications of polymers. Recycling of polymers. Composites- Introduction, types. Wood, Concrete, FRP and some advanced composites. Properties and applications.

UNIT-III	Ceramics and Glasses	15 Hours

Ceramics: Introduction, classification, raw materials, fabrication methods, properties and applications. Types of ceramics- oxide and non-oxide ceramics. Allotropes of carbon- graphite, diamond and fullerene. Primary refractory materials. Glasses: Introduction, raw materials, manufacture of glass, properties and applications. Types of glasses, properties and applications.

UNIT-IV	Responsive Materials	15 Hours

Introduction, Piezoelectric materials, Shape memory alloys and polymers, Electrochromic and photochromic materials, Magnetostrictive materials. Mechanism of action,

Applications: Sensors, actuators, and transducers.		
UNIT-V	**Technological advancements with Materials**	**10 Hours**
Introduction, Applications: Aerospace, Automobile, Consumer electronics, Smart textiles, Biomedical - implants and prosthetics		
	Total Lecture Hours	**72 Hours**
Textbooks/References		

Textbooks:

3. Materials Science and Engineering – V Raghavan (Prentice Hall India,1993)
4. Introduction to Solids – A J Dekker (McMillan India, 1981)
5. Materials Science and Engineering-An Introduction 7e, William D. Callister, (Wiley, 2007).

Books for Reference:

1. Foundations of Materials Science and Engineering – William F. Smith, Javad Hashemi, and Ravi Prakash
2. Electronic Properties of Materials – Rolf E. Hummel
3. Materials Science- Nagpal (Khanna, Delhi)
4. Polymer Science and Technology – Joel R. Fried
5. Introduction to Composite Materials Design – Ever J. Barbero
6. Introduction to Ceramics – W D Kingery, H K Bowen and Donald R. Uhlman
7. Glasses and vitreous state – J Zarzycki
8. Biomaterials: The Intersection of Biology and Materials Science – Johnna S. Temenoff and Antonios G. Mikos

Course Code	NSP7E 505	PHYSICS IN EVERYDAY LIFE	L	T	P	C
Open Elective			4	0	0	4
Prerequisite	Basic knowledge in science		Syllabus Version	2024		

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- Understand various fundamental physics concepts in daily life.
- Apply Physics concepts to the real world problems and scenarios.
- Explore the role of Physics in technology.
- Analyze how Physics is used in various fields.

Course Outcomes

1. Remember fundamental concepts of Physics – K1
2. Understand the Physics behind various natural phenomena – K2
3. Identify the role of Physics in addressing global challenges and issues – K2, K3
4. Analyze and evaluate the Physics of fluids and thermodynamics in everyday life – K4, K5

K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate

UNIT-I	Physics of the Universe	15 Hours

Universe: Galaxy, Star, Solar system, Sun, Earth's atmosphere as an ideal gas; Pressure, temperature and density, Pascal's Law and Archimedes' Principle, Coriolis acceleration and weather systems, Rayleigh scattering, Red sunset, Reflection, refraction and dispersion of light.

UNIT-II	Physics in Human body	12 hours

ectromagnetic interaction with human body, Longitudinal and transverse waves, The eyes as an optical instrument, Vision defects, Rayleigh criterion and resolving power, Sound waves and hearing, Sound intensity, Decibel scale, and temperature control.

UNIT-III	Physics in Technology	13 Hours

Global Positioning System, Smartphone, Quantum computers, Lasers, Displays, Optical recording, Memory devices, Electric motors, Hybrid car, Telescope, CCDs, Microscope, Projector etc.

UNIT-IV	Physics in the Kitchen	10 Hours

Microwave ovens, Lorentz force, Pressure cooker, Boyles law, Refrigerator, thermodynamics of refrigerator, Air fryer, heat convection, Renewable and non-renewable energy sources, LPG, Electricity, Smoke detector, Leverage principles, Kitchen scales.

UNIT-V	Physics in Sports	10 Hours

The sweet spot, Running, Jumping and pole vaulting, Javelin throw, Projectile motion, Dynamics of rotating objects, Motion of a spinning ball, Continuity and Bernoulli equations, Banana kick: Magnus effect, Turbulence and drag.

	Total Lecture Hours	60 Hours
Textbooks/References		

Textbooks:

1. Fundamentals of Physics by D. Halliday, R. Resnick, J. Walker, John Wiley & Sons
2. The Sun, Stars, and Galaxies by Britannica Educational Publishing 2011
3. University Physics by F. W. Sears, M. Zemansky, R. A. Freedman, and H. D. Young, Pearson Education
4. The Physics of Everyday life by Louis A Bloomfield
5. Physics in Everyday life by W Thomas Griffith

Books for Reference:

1. Physics in the Kitchen, George Vekinis, Springer Nature Switzerland, 2023.
2. The Physics of Cricket, Mark Kidger, Nottingham University Press, 2011.
3. The Science of Soccer, John Wesson, Institute of Physics Publishing, 2002.
4. How Things Work 6th Ed, Louis A Bloomfield, John Wiley & Sons, 2016.

NSP7M 501 MOOC I ONLINE Course - 4 Credits

Course Code	NSP8C 504	STATISTICAL MECHANICS	L	T	P	C
Core			3	0	1	4
Pre-requisite	Basic knowledge in physical science		Syllabus Version	2024		

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- Recognize the statistical foundations of thermodynamics
- Understand the fundamental principles of equilibrium statistical physics
- Analyse the connection and dichotomy between classical and quantum statistics
- Learn the behaviour of Bose and Fermi gases based on quantum statistical physics
- Familiarise phase transitions and non-equilibrium statistical mechanics

Course Outcomes

1. Discuss the connection between statistics and thermodynamics – K4
2. Demonstrate and understand the terminology, concepts and principles related to physical systems in a statistical mechanical framework – K3
3. Derive partition function and compute thermodynamics relations for various real-world physical systems – K6
4. Explain aspects of the statistical physics of systems with an interaction between its constituent components – K4

K1- Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate K6- Create

UNIT-I	Foundations of Statistical Mechanics & Ensemble Theory	12 Hours

Specification of states of a system, Contact between statistics and Thermodynamics, Classical Ideal gas, Entropy of mixing and Gibbs paradox, Sackur-Tetrode Equation.

Microcanonical ensemble, phase space, trajectories and density of states, Liouville's theorem, canonical and grand canonical ensembles, partition function, Equipartition Theorem, calculation of statistical quantities.

UNIT-II	Quantum Statistical Mechanics:	12 hours

Density matrix, statistics of Microcanonical, Canonical and Grand canonical Ensemble, Example: Electron in a magnetic field, Free Particle in a box, Statistics of indistinguishable particles.

UNIT-III	Ideal Systems	11 Hours

Density matrix of a system of non-interacting particles. Ideal gas in quantum mechanical ensembles, Maxwell-Boltzman, Fermi-Dirac and Bose-Einstein statistics, Thermodynamics of ideal Bose and Fermi gases, Bose-Einstein condensation.

UNIT-IV	Phase Transitions and Fluctuations	10 Hours

Problem of condensation, Yang and Lee Theory, Dynamical model of Phase transitions, Ising Model in Zeroth approximation, Equilibrium thermodynamic Fluctuations, Brownian motion and Langevin theory, Exercises.

UNIT-V	General Physics Experiments:	30 Hours

- Millikan's Oil Drop experiment: To confirm the quantization of charge and to determine the charge of electron.
- Ultrasonic interferometer: Determination of ultrasonic sound velocity in liquids.

- Verification of Coulomb's law using Coulomb balance.
- Measurement of thermal conductivity of thermal insulators using Lee's disc apparatus.
- Determination of surface tension of water by Jaeger's method.
- Determination of Cauchy's constant using spectrometer.

	Total Lecture + Practical Hours	**75 Hours**

Text Books/References

1. R. K. Pathria. "Statistical Mechanics" (3^{rd} Edition, Elsevier, 2011)
2. K Huang : "Statistical Mechanics" (2^{nd} Edition, John Wiley(NY), 1987).
3. F. Reif : "Statistical and Thermal Physics" (Tata McGraw Hill(ND), 2008).
4. Landau and Lifshitz : "Statistical Physics Part 1" (3^{rd} edition, Elsevier, 2011).
5. Statistical Mechanics and Properties of Matter – E S R Gopal (McMillan India, 1976)
6. Statistical Physics: Berkeley Physics(5) – F Reif (McGraw Hill,1967)

<table>
<tr><td>Course Code</td><td>NSP8C 505</td><td rowspan="2">ELECTRODYNAMICS</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Core</td><td>3</td><td>0</td><td>1</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge in general Physics</td><td colspan="2">Syllabus Version</td><td colspan="2">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
</table>

Course Objectives

The main objectives of the course are to:

- Understand the fundamental theories associated with electrostatics and magnetostatics
- Analyse the propagation of electromagnetic waves through conducting and nonconducting media.
- Understand the propagation of electromagnetic waves through confined media
- Understand special theory of relativity and the relativistic formulation of electrodynamics.

Course Outcomes

1. Solve boundary value problems and wave equations and analyse the results - K4
2. Understand basic concepts related to wave propagation and few of their applications - K3
3. Understand electromagnetic wave propagation through waveguides and analyze the specific field patterns from antennas - K4
4. Understand the blending of relativity and electrodynamics that motivates to study quantum field theory and symmetries - K5

K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6- Create

UNIT-I	**Electrostatics & Magnetostatics**	**12 Hours**

Boundary value problems, Formal solution with Green’s functions, electrostatic potential energy. Method of images- Point charge near a grounded conducting sphere, Point-charge near a charged insulated conducting sphere, conducting sphere in a uniform electric field. Laplace equation in spherical polar coordinates- Boundary value problem with azimuthal symmetry. Multipole expansion Electrostatic multipole moments - energy of a charge distribution in an external field.

Biot-Sawart Law and its differential statement, Ampere’s law. Vector potential, Macroscopic equations, Boundary conditions on B and H, Methods of solving boundary-value problems in magnetostatics.

UNIT-II	**Time Varying Fields**	**11 hours**

Faraday’s Law of electromagnetic induction - energy in a magnetic field – displacement current - Maxwell’s equations. Vector and scalar potentials - gauge transformations - Lorentz gauge, Coulomb gauge, Poynting’s theorem and conservation of energy and momentum, complex Poynting vector. Boundary conditions for the electric and magnetic fields at an interface- Plane electromagnetic wave in a non-conducting medium, linear and

circular polarization, reflection and refraction at a dielectric interface, polarization by reflection and total internal reflection		
UNIT-III	**Waveguides and Radiating Systems**	**10 Hours**
. Penetration of fields into the conductors, cylindrical cavities and waveguides, metallic waveguides, modes in a rectangular waveguide, resonant cavities. Simple radiating systems: Green's function for wave equation, fields and radiation of a localized oscillating source - electric dipole field and radiation, magnetic dipole and electric- quadrupole fields.		
UNIT-IV	**Relativistic Electrodynamics**	**12 Hours**
Special Theory of Relativity, Postulates of relativity, Lorentz transformations, four vectors, addition of velocities, four velocity, relativistic momentum and energy, mathematical properties of space-time, matrix representation of Lorentz transformation. Dynamics of relativistic particles. Lagrangian and Hamiltonian of relativistic charged particle, motion in a uniform static electric and magnetic field.		
UNIT-V	**General Physics-Experiments**	**30 Hours**
▪ Diffraction experiments: I. Determination of wavelength of laser light using diffraction grating II. Measurement of thickness of a thin wire ▪ Photoelectric effect: Determination of Planck's constant and work function Determination of e/m ratio using Thomson's method. ▪ Study of magnetoresistance of a semiconductor. ▪ Determination of Lande's g-factor of a free radical using ESR spectrometer. ▪ Study of magnetic susceptibility of materials using Gouy Balance. ▪ Dielectric constant of solids and liquids. ▪ Study of magnetic hysteresis of ferromagnetic materials.		
	Total Lecture + Practical Hours	**75 Hours**
Text Books/References		
1. J. D. Jackson, Classical Electrodynamics. 2. David J Griffiths, Introduction to Electrodynamics.		

<table>
<tr><td>Course Code</td><td>NSP8C 506</td><td rowspan="2">QUANTUM MECHANICS- I</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Core</td><td>3</td><td>0</td><td>1</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge in general physics, Chemistry and mathematics.</td><td>Syllabus Version</td><td colspan="3">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
</table>

Course Objectives
• Understand the evolution of quantum mechanics. • Introduce the quantum mechanical postulates in physical systems. • Learn quantum mechanical formalism for different physical systems • Learn the concepts of angular and spin moneta.
Course Outcomes
1. Learn to describe the failure of classical mechanics for microscopic systems – K1, K2 2. Understand different postulates and Learn to Solve Schrodinger equation for simple systems − K3, K4 3. Understand angular momentum and spin dynamics of quantum systems and to solve angular momentum using CG coefficients – K3, K4 4. Problem solving, evaluation and analysis capacity – K3, K4, K5
K1– Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate

UNIT-I	**Origin of quantum mechanics**	**10 Hours**
Blackbody radiation. Plank's quantum hypothesis, Einstein's photoelectric effect, wave particle duality-de Broglie matter waves, Electron diffraction, Heisenberg's Matrix Mechanics (brief mention), Schrodinger wave mechanics, Deduction of Schrodinger equation from classical wave equation.		
UNIT-II	**Postulates of quantum mechanics**	**10 hours**
All postulates in detail. Wave function postulate. Operator postulate. Eigen value postulate. Expectation value postulate. Time dependent postulate. Formulation of quantum mechanical problem. Solving problems.		
UNIT-III	**Quantum mechanics in different systems**	**13 Hours**
Quantum mechanics of translational motion- particle in 1D and 3D box. Tunneling. Vibrational motion- One-dimensional harmonic oscillator. Rotational motion- Rigid rotator. Spherical harmonics. Quantization of angular momentum, quantum mechanical operators corresponding to angular momenta ((Lx, Ly, Lz), commutation relations between these operators. Matrix Representation of Angular Momentum Operators. Addition of angular momenta. Clebsh-Gordon coefficients. Spin Angular Momentum- Spin 1/2 and the Pauli Matrices. Coupling of Orbital and Spin Angular Momenta.		
UNIT-IV	**Quantum mechanics of Hydrogen like atoms**	**12 Hours**
Potential energy of hydrogen-like systems. The wave equation in spherical polar coordinates, Separation of variables. The R, Theta and Phi equations and their solutions. Wave functions and energies of hydrogen-like atoms, Orbitals. Radial functions and Radial distribution of functions and their plots Angular functions and their plots, Orbital diagrams. Hydrogen spectrum. The postulate of spin by Unlebeck and Goldsmith, Dirac's Relativistic Schrodinger equation for hydrogen atom and discovery of spin.		

UNIT-V	Computational Lab I	30 Hours
• Use of different software for data analysis • Writing Z-matrix • Graph plotting • Familiarizing different software for reference management • Use of chemdraw/chemsketch/marvinsketch		
	Total Lecture Hours	**75 Hours**
Text Books/References		

1. A Text Book of Quantum Mechanics, P.M. Mathews & K. Venkatesan, Tata McGraw Hill, (2010).
2. Quantum Chemistry, Donald, A. McQuarrie, University Science Books, 1983 (first Indian edition, Viva books, 2003).
3. Modern Quantum Mechanics, J. J. Sakurai and Jim Napolitano, Cambridge University Press, third edition, 2020.
4. Problems and solutions in quantum mechanics, K. Tamvakis, Cambridge University Press, 2005.
5. Quantum Physics, Florian Scheck, Springer Science & Business Media, 2007.
6. Introduction to Quantum Mechanics, David J. Griffiths, Cambridge University Press.
7. Quantum Chemistry, I.N. Levine, 6th Edition, Pearson Education Inc.,
8. Molecular Quantum Mechanics, P.W. Atkins and R.S. Friedman, 4th Edition, Oxford University Press, 2005.
9. Quantum Mechanics in Chemistry, M.W. Hanna, 2nd Edition, W.A. Benjamin Inc., 1969.
10. Physical Chemistry – Quantum Mechanics, HoriaMetiu, Taylor & Francis, 2006.
11. Introduction to Quantum Mechanics, L. Pauling and E.B. Wilson, McGraw-Hill, 1935 (A good source book for many derivations).
12. Quantum Chemistry, R.K. Prasad, 3rd Edition, New Age International, 2006.
13. Lectures on Chemical Bonding and Quantum Chemistry, C.N. Datta, Prism Books Pvt. Ltd., 1998.

Course Code	NSP8E 506	PRECISION NANOCLUSTERS: ORIGIN AND APPLICATIONS	L	T	P	C
Elective			3	0	1	4
Pre-requisite			Syllabus Version		2024	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

1. To understand the applications of various precision nanomaterials in different aspects of science.
2. To Analyze the potentials of precision nanoprobes in cancer therapeutics.
3. To evaluate the uses of different nanoprobes in catalysis, sensing, fabrication of solar cells and light-emitting devices.
4. To create new functional nanoprobes for advanced applications.

Course Outcomes

1. This course is designed to understand (K1) the applications of precision nanomaterials in different aspects of science, including catalysis, sensing, fabrication of solar cells and light-emitting devices, and biology (K3, K6).
2. This particular course module will help students to analyse (K2) each precision nanoprobe at the laboratory level.
3. Towards the end of this course, students could evaluate (K3) which precision nanoprobes will be ideal for specific applications.
4. Such experience will help to create (K4) novel precision materials during their Ph.D. career.

K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6-Create

UNIT-I	Precision Nanoclusters: Origin, Synthesis, & Characterization	12 Hours

Polydisperse nanoparticles to monodisperse nanoparticles and monodisperse nanoparticles to atomically precise nanoclusters – Brust synthesis and beyond. Electronic and geometric stability of nanoclusters (magic numbers). Size-focused synthesis of gold nanoclusters (eg: $Au_{25}(SR)_{18}$): chemical reduction method, LEIST methodology, carbon monoxide reduction method. Different isolation techniques: fractionated precipitation, recrystallization, solvent extraction, polyacrylamide gel electrophoresis, size exclusion chromatography, high performance liquid chromatography, thin layer chromatography. Crystal structure of nanoclusters (eg: $Au_{25}(SR)_{18}$).

UNIT-II	Optical Properties of Nanoclusters	8 hours

Optical properties: Optical absorption and photoluminescence, aggregation-induced emission, electrochemical properties (Brief).

UNIT-III	Chemistry of Nanoclusters	13 Hours

Ligand exchange, ligand conjugation: coupling reaction (EDC or DCC) and click reaction. Self – assembly of nanoclusters using various molecular driving forces (eg: hydrogen bonding, electrostatic interactions, Van der Waals interactions, dipolar interactions, C-H$\cdots\pi$/$\pi\cdots\pi$ interactions, amphiphilicity, metal chelation, metal – metal interactions, light-triggered dipole – induced attractions, and external templates).

UNIT-IV	Applications of Nanoclusters	12 Hours
Catalysis – oxidation (eg: CO, alcohol), hydrogenation (selective, alkyne, nitro compounds), electron – transfer catalysis, electrocatalysis, photocatalysis. Sensors: cation or anion sensing, biosensing (eg; glucose, ATP, protein, and nucleic acid). Applications in solar cells and light – emitting devices. Biological applications: biolabeling, bioimaging, and cancer therapeutics: photodynamic, and photothermal therapy.		
UNIT-V	**Practical**	**30 Hours**
1. Estimation of ferrous ions by cerimetry titration 2. Estimation of nitrite ion by cerimetry titration 3. Determination of viscosity of pure liquids 4. Determination of composition of binary liquid mixture using viscometer 5. Preparation of salicylaldehyde from phenol 6. Preparation of *p*-nitroaniline from acetanilide		
	Total Lecture + Practical Hours	**75 Hours**

Text Books/References

1. Atomically precise nanoclusters, Zhu, Y.; and Jin, R. Jenny Stanford Publishing Ltd., (2021).
2. Atomically precise metal nanoclusters, Wu, Z.; and Jin, R.; Morgan & Claypool (2020).
3. Protected metal clusters from fundamentals to applications, Tsukuda, T.; Häkkinen, H. Elsevier (2015).
4. Precision nanoclusters, Pradeep et al. Elsevier (2022).
5. Chakraborty, I.; Pradeep, T. Atomically precise clusters of noble metals: Emerging link between atoms and nanoparticles. Chem. Rev. 2017, 117, 8208-8271.
6. Jin, R.; Zeng, C.; Zhou, M.; Chen, Y. Atomically precise colloidal metal nanoclusters and nanoparticles: Fundamentals and opportunities. Chem. Rev. 2016, 116, 10346-10413.
7. Kang, X.; Zhu, M. Tailoring the photoluminescence of atomically precise nanoclusters. Chem. Soc. Rev. 2019, 48, 2422-2457.
8. Rival, J. V.; Mymoona, P.; Lakshmi, K. M.; Nonappa; Pradeep, T.; Shibu, E. S. Self-assembly of precision noble metal nanoclusters: Hierarchical structural complexity, colloidal superstructures, and applications. Small 2021, 17, 2005718.
9. Vogel's textbook of qualitative inorganic analysis; G. Svehla and B. Sivasankar; Longman Scientific & Technical.
10. Experiments in physical chemistry; D. F. Schomaker and C. W. Garland; McGraw Hill.
11. Experimental physical chemistry; Gurdeep Raj; Krishna Prakasha.
12. Vogel’s textbook of practical organic chemistry, A. R. Tatchell, John Wiley.

Course Code	NSP8E 507	NANOSTRUCTURED SOLAR CELLS	L	T	P	C
Elective			4	0	0	4
Pre-requisite	Basic knowledge in Nanoscience		Syllabus Version		2024	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Conscious of energy crisis, its reason, current status and possible solutions
2. Recognize renewable and non-renewable energy resources and their contribution towards global energy production
3. Importance of re-newable energy resources and tapping such energies
4. Role of Nanoscience or nanotechnology in producing novel materials and designs for efficient production of energy using renewable resources

Course Outcomes

1. Analyze the reasons for energy crisis and understand the importance of sustainable energy development (K4,K2)
2. Understand Hydrogen economy and advantages and challenges of Hydrogen fuel and its production (K2)
3. Understand the possibilities of solar energy production using nanostructured materials and create awareness on using solar panels for house hold and other energy usages. (K2,K6)
4. Analyze the importance of different design architectures for efficient tapping of solar energy using nanoscience (K4)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Primary Perspective in Energy Conversion	10 Hours

Current energy scenario; Energy and climate: - Greenhouse effect, conventional energy sources Vs non-conventional energy sources. Outline of alternative energy schemes – solar, wind, biomass, hydro, and nuclear. Clean low cost, sustainable energy development, prospects of renewable energy.

UNIT-II	Photovoltaic Solar Energy Conversion	14 Hours

Properties of sunlight: Solar radiation at earth's surface- Air Mass. Semiconductors and junctions, carrier generation, Recombination, Carrier Transport, Solar cell operation, Principles of photovoltaic energy conversion (PV), Solar cell parameters, Factors affecting the solar cell efficiency, Types of photovoltaic Cells.

UNIT-III	Silicon Solar Cells	16 Hours

Si solar cells- Structure, and working. Optical properties, optical losses, antireflection coating, light trapping. Reducing recombination, Silicon solar cell manufacturing, Silicon wafers, processing technologies, solar cell fabrication technologies, Modules and arrays, inter connection issues, temperature effects and other effects. Efficiency measurements, IV Characterization, Life time etc. General materials properties of silicon. Types of silicon solar cells.

UNIT-IV	Nanostructured Solar Cells	15 Hours
Fundamentals of nanostructured solar cells, nanostructures in conventional thin film solar cells. Dye sensitized solar cells (DSSC), Design and working. Quantum dot sensitized solar cells (QDSSC), Design, working and charge transfer kinetics. Organic solar cell, Organic-Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Nanostructured ETA solar cells, Current status and future direction.		
UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**60 Hours**
Text Books/References		

1. Nanostructured Materials for Solar Energy Conversion, By Tetsuo Soga, 2006 Elsevier B.V. All rights reserved.
2. PVCDROM, "*www.pveducation.org*",
3. Aldo V. da Rosa, *Fundamentals of Renewable Energy Processes, 2nd Edition* (Elsevier Academic Press, 2009).
4. Green Chemistry and Chemical Engineering, Pronton Exchange Membrane Fuel Cells Contamination and Mitigation Strategies, By hui Li, Shanna Knights, Zheng Shi, John W. Van Zee, Jin Jun Zhang, Taylor and Francis Group, 2010, USA.
5. Martin A. Green, *Solar Cells: Operating Principles, Technology, and System Approaches* (Prentice-Hall, 1998)
6. Jenny Nelson, *The Physics of Solar Cells* (Imperial College Press, 2003)
7. D. Linden Ed., Handbook of Batteries, 2nd edition, McGraw-Hill, New York (1995)
8. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kulwer Acdemic Publishers, Dordrecht, Netherlands (2004).
9. J. Larmine and A. Dicks, Fuel Cell System Explained, John Wiley, New York (2000).

Course Code	NSP8E 508	SOLID STATE PHYSICS OF MATERIALS	L	T	P	C
Elective			4	0	0	4
Pre-requisite	Basic knowledge in solid state physics		Syllabus Version		2024	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- Elaborate the fundamental understanding of solid state physics of materials
- Provide in depth knowledge of energy band structure of solid state materials
- Enumerate the physical properties of solid state materials
- Provide knowledge on alloys, superconducting materials and liquid crystals

Course Outcomes

The course outcomes can be as follows:

1. Understand the band structure of solids - K2, K3
2. Apply the basic properties for realizing the applications – K3, K5
3. Apply the knowledge of band structures to estimate the bandgap of nanomaterials – K3, K4
4. Apply the fundamental knowledge of bulk solids to enumerate and evaluate the properties of nanostructured materials – K3, K5, K6

K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate K6 – Create

UNIT-I	Metallic Materials	11 Hours

Band structure of metals - Brillouin zones, Wigner Seitz approximation, Energy wave vector curves, Brillouin zones relationship with Bragg plane, Density of states, Fermi surface – FCC & BCC structures – De Haas van Alphen effect. Electronic properties of metals – Boltzmann transport equation, Electrical conductivity, Thermal conductivity, Galvanomagnetic effects, Thermionic and Field emission in metals.

UNIT-II	Semiconductor Materials	13 hours

Energy bands, Effective mass, Direct and indirect bandgap in semiconductors, Determination of bandgap, Donors and acceptors, Carrier concentrations at thermal equilibrium, Calculation of Fermi level, Degenerate and non-degenerate semiconductors. Semiconductor Crystal growth – Introduction, Methods: Bridgman, Czochralski, zone melting/refining techniques. Analysis of contact phenomenon: semiconductor-semiconductor, metal-semiconductor contacts, Schottky and Ohmic contacts, Semiconductor devices fabrication: Fabrication of junctions - wafer preparation, IC technology: monolithic IC, masking and etching, elements of lithography.

UNIT-III	Insulator Materials	13 Hours

Heat capacity of Insulators, Einstein's model, Quantisation of lattice vibration - continuum model, Debye's theory. Vibrations of monoatomic lattice - specific heat of one dimensional lattice of identical atoms. Phonon spectra of diatomic lattice and phonon modes - optical properties in infra-red region and their applications. Scattering of electromagnetic waves and neutrons by phonons. Thermal conductivity of insulators - lattice thermal resistivity -

Umklapp process. Thermal expansion: Potential wells in crystal binding - anharmonic interactions and thermal expansion of insulators.		
UNIT-IV	**Alloys and Superconducting Materials**	**13 Hours**
Alloys: Long range order theory, Super lattices and transitions. Diffusion in alloys - Darken's equations, Determination of diffusion coefficient. Special alloys - ferrous and non-ferrous. Super alloys. Meissner effect, Type I and Type II superconductors, Heat capacity, Microwave absorption, Energy gap, Isotope effect, Free energy of superconductor in magnetic field and the stabilization energy, London equation and penetration of magnetic field, Cooper pairs and the BCS theory, DC and AC Josephson effects.		
UNIT-V	**Liquid Crystalline Materials**	**10 Hours**
Classification of liquid crystals, Elementary ideas. Properties of liquid crystals - birefringence, dielectric anisotropy, viscosity, conductivity anisotropy and elasticity of liquid crystals, electro-optic, thermo-optic effects, LCD devices and applications.		
	Total Lecture Hours	**60 Hours**
Text Books/References		
1. Solid State Physics – A J Dekker (McMillan, 1985) 2. Solid State Physics – C Kittel (Wiley Eastern, 1993) Solid State Physics –N W Ashcroft and N D Mermin (W B saunders, Ithaca, 1976) 3. Electronic Materials and devices – D. K. Ferry (Academic Press, New York, 2001) 4. Semiconductor Physics – P S Kireev (MIR Publishers, 1978) 5. Physics of Semiconductors Devices – S M Sze (Wiley Eastern, 1991) 6. Solid State Devices – Ben G Streetman (Prentice-Hall, 1995) 7. Solid State and Semiconductor Physics – John Mckelvey (John Wiley, 1976) 8. Introduction to properties of Materials – Daniel Rosenthal and Robert M Asimow (Affiliated East-West Press, 1974) 9. Nuclear Reactor Engineering – S Glasstone and Alexander Sesonske (CBS Pub., 1986) 10. Liquid Crystals – S Chandrasekhar (Cambridge University Press, 1977)		

NSP8M 502 MOOC II ONLINE Course - 4 Credits

Course Code	NSP9C 601	**NUCLEAR AND PARTICLE PHYSICS**	L	T	P	C
Core			4	0	0	4
Pre-requisite	Basic knowledge in nuclear and particle physics.		Syllabus Version		2024	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- Understand the fundamental concepts of nuclear structure and models.
- Learn the method of solving problems of different nuclear models and particle physics.
- Understand the concepts of different types of nuclear interactions.
- Learn the method of evaluation of conservation laws and symmetries.

Course Outcomes

1. Remember the fundamentals of concepts and principles of nuclear structure and models – K1
2. Understand concepts of different types of nuclear interactions and reactions – K2
3. Understand different conservation laws and symmetries of particle physics and solving problems based on it – K3
4. Problem solving, evaluation and analysis capacity – K5

K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6- Create

UNIT-I	Nuclear Structure and Models	14 hours

Basic properties of nucleus: - Nuclear radius, distribution of nuclear charge, skin thickness, isotope shift, nuclear matter distribution, nuclear binding energy, Magnetic dipole moment - quadruple moment - Liquid drop model - Semi-empirical mass formula of Weizsacker - Nuclear stability - Mass parabolas - Bohr-Wheeler theory of fission - Shell model - Spin-orbit coupling - Magic Numbers-Elementary ideas of collective model.

UNIT-II	Nuclear Interactions	14 Hours

Nuclear forces - Two body problem - Ground state of deuteron - Meson theory of nuclear forces - Yukawa potential - Nucleon-nucleon scattering - Low energy n-p scattering - Effective range theory - Spin dependence, charge independence and charge symmetry of nuclear forces - Isospin formalism

UNIT-III	Nuclear Reactions	16 Hours

Radioactivity, Types of reactions and conservation laws - Reaction dynamics-Q-value equation Basics of alpha decay and Gamow's theory of Alpha decay, beta decay and energetic of beta decay, Fermi's theory of Beta decay, Kurie plots, Mass of the neutrino, life time, Allowed and forbidden transitions, selection rules and parity violation in beta decay, Neutrino physics - Non-conservation of parity - Gamma decay - Internal conversion - Multipole moments, life times. Energetics of fission process, controlled fission reactions, fusion process and solar fusion.

UNIT-IV	Particle Physics	16 Hours
Elementary particles; Types of interactions between - Hadrons and Leptons - Symmetry and conservation laws; Elementary ideas of CP and CPT invariance - Classification of Hadrons - SU (2) - SU (3) multiplets - Quark model - Gell-mann-Okubo mass formula for octet and decuplet Hadrons – Quantum chromo dynamics (QCD)-Elementary ideas of standard model of weak interaction and QCD		
	Total Lecture Hours	**60 Hours**
Text Books/References		

1. K.S. Krane, 1987, Introductory Nuclear Physics, Wiley, New York.
2. D. C Thayal, Nuclear Physics, Himalaya Pub. House 1997
3. Y.Neeman and Y.Kirsh: "The particle hunters' (Cambridge University Press)

Course Code	NSP9C 602	QUANTUM MECHANICS II	L	T	P	C
Core			3	0	1	4
Pre-requisite	Basic knowledge in general physics, Chemistry and mathematics.		Syllabus Version	2024		

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- Understand various approximation techniques & relativistic quantum mechanics to solve simple systems.
- Learn the concepts of group theory and symmetry for different chemical systems.
- Describe the spectra and bonding in compounds in connection with group theory.
- Learn different computational software and solve simple molecular systems.

Course Outcomes

1. Solve different molecular systems by suitable approximations – K2, K3, K4
2. Understand the fundamentals spectral transitions and bonding at the molecular level – K3, K4, K5
3. Learn to use different computational softwares – K2, K3, K6
4. Solve simple chemical problems computationally – K3, K6

K1– Remember, K2 – Understand, K3 – Apply, K4 – Analysis, K5 – Evaluate, K6- Create

UNIT-I	Approximation Methods	11 hours

Perturbation theorem: The WKB approximation, Connection formulae, Barrier tunneling, Application to decay- bound states, Penetration of a potential barrier, Time- independent perturbation theory. Illustration by application to particle in ID-box with slanted bottom, Perturbation treatment of the ground state of the helium atom. Transition probability. Variation theorem: The variational equation with proof, ground state and excited states, the variation method for bound states, Application to ground state of the hydrogen and helium atoms. HFSCF Method.

UNIT-II	Relativistic Quantum Mechanics	11 Hours

The Dirac equation, Dirac matrices, Solution of the free-particle Dirac equation. Spin-orbit coupling, Covariance of the Dirac equation, Bilinear covariants, Hole theory, The Weyl equation equation for the neutrino, Nonconservation of parity, The Klein Gordon equation, Charge and current densities, The Klein- Gordon equation, Charge and current densities, The Klein –Gordon equation equation with potentials, Wave equation for the photon,Charge conjugation for the Dirac, Weyl and Klein Gordon equation.

UNIT-III	Theories of molecular symmetry	11 Hours

Introduction to symmetry and point groups. Group multiplication tables. Similarity transformation. Reducible and irreducible representations. Construction of irreducible representations by reduction (similarity transformation). Great orthogonality theorem (GOT) and properties of irreducible representations using GOT, Construction of character Table (C2v, C3v, C2h, C4v). Nomenclature of irreducible representations - Mulliken symbols, Symmetry species. Reduction formula using GOT.

UNIT- IV	Applications of Group Theory	12 Hours

a. Vanishing and non-varnishing integrals. Transition moment integral and selection rules. Overlap integrals and conditions for overlap. Electronic transitions and selection rules, Laporte selection rule for Centro symmetric molecules.
b. Molecular vibrations, Selection of rules for IR and Raman activities, complementary character of IR and Raman spectra, Determination of IR active and Raman active modes of molecules.
c. Molecular orbital treatment of molecules using Group theory. Treatment of H_2O.
d. Group theoretical treatment of hybridization, Construction of hybrid orbital in BF3 and Inverse transformation.

UNIT-V	**Computational Lab-II**	**30 Hours**

- Use of different graphical user face
- Plotting experimental data by different software
- PES and Geometry optimization of small molecules

Computing quantum chemical descriptors

	Total Lecture Hours	**75 Hours**

Text Books/References

5. A Text Book of Quantum Mechanics, P.M. Mathews & K. Venkatesan, Tata McGraw Hill, (2010).
6. Quantum Chemistry, Donald, A. McQuarrie, University Science Books, 1983 (first Indian edition,Viva books, 2003).
7. Modern Quantum Mechanics, J. J. Sakurai and Jim Napolitano, Cambridge University Press, third edition, 2020.
8. Problems and solutions in quantum mechanics, K. Tamvakis, Cambridge University Press, 2005.
9. Quantum Physics, Florian Scheck, Springer Science & Business Media, 2007.
10. Introduction to Quantum Mechanics, David J. Griffiths, Cambridge University Press.
11. Quantum Chemistry, I.N. Levine, 6th Edition, Pearson Education Inc.,
12. Molecular Quantum Mechanics, P.W. Atkins and R.S. Friedman, 4th Edition, Oxford University Press, 2005.
13. Quantum Mechanics in Chemistry, M.W. Hanna, 2nd Edition, W.A. Benjamin Inc., 1969.
14. Physical Chemistry – Quantum Mechanics, HoriaMetiu, Taylor & Francis, 2006.
15. Introduction to Quantum Mechanics, L. Pauling and E.B. Wilson, McGraw-Hill, 1935 (A good source book for many derivations).
16. Quantum Chemistry, R.K. Prasad, 3rd Edition, New Age International, 2006.
17. Lectures on Chemical Bonding and Quantum Chemistry, C.N. Datta, Prism Books Pvt. Ltd., 1998.

Course Code	NSP9C 603	MOLECULAR SPECTROSCOPY	L	T	P	C
Core			3	0	1	4
Pre-requisite	Basic knowledge in general spectroscopy		Syllabus Version		2024	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- Understand the fundamental concepts and principles in molecular spectroscopy.
- Learn the method of solving problems for different molecular systems.
- Understand the concepts of different types of spectra.
- Learn the method of evaluation of chemical problems spectroscopically.

Course Outcomes

- Remember the fundamentals of concepts and principles in molecular spectroscopy – K1
- Understand concepts of different types of spectra – K2
- Understand different chemical systems with different types of spectra and solving problems based on it – K2, K3
- Problem solving, evaluation and analysis capacity – K3, K4, K5

K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6- Create

UNIT-I	Microwave Spectroscopy	11 hours

General theory of spectra: Electromagnetic radiation and its different regions, quantization of energy, interaction of matter with radiation and its effect on the energy of the molecule. Origin of molecular spectra. Rotation spectra of diatomic and polyatomic molecules, rigid and non-rigid rotator models, asymmetric, symmetric, and spherical tops. Isotope effect on rotation spectra, Stark effect, nuclear and electron spin interactions. Rotational transitions and selection rules. Microwave spectrometer - principle & applications.

UNIT-II	IR and Raman Spectroscopy	11 Hours

Vibrational spectra of diatomic and polyatomic molecules, harmonic oscillator model, anharmonicity. Vibrational transitions and selection rules. Morse potential, fundamentals, overtones, hot bands, combination hands, difference bands. Vibrational spectra of diatomic and polyatomic molecules, P, Q, R branches. IR and FT-IR spectrophotometer – principle, instrumentation, and applications. Pure rational, pure vibrational Raman spectra, vibrational, rotational Raman spectra, selection rules, mutual exclusion principle. Raman spectrophotometer – principle, instrumentation. Laser Raman spectroscopy, and applications.

UNIT-III	Electronic Spectroscopy	11 Hours

Basic principle, Beer-Lambert’s law, Molar extinction coefficient, intensity of electronic transitions. Types of electronic transitions. Franck – Condon principle, ground, and excited electronic states of diatomic molecules. Electronic spectra of polyatomic molecules. The fate of electronically excited state species – vibrational relaxation, external conversion, internal conversion, fluorescence, phosphorescence, Jablonski diagram. Electronic spectra of conjugated molecules – dissociation and predissociation spectra. UV-Visible and fluorescence spectrophotometer – principle and applications.

UNIT-IV	Resonance Spectroscopy	12 Hours

Interaction between nuclear spin and magnetic field, level population, Larmor precession, resonance condition, Bloch equations, relaxation times, spin-spin and spin-lattice relaxation, chemical shift, instrumentation for NMR spectroscopy, electron spin resonance spectroscopy (ESR/EPR) of the unpaired electron, total Hamiltonian, fine structure, electron-nucleus coupling and hyperfine structure.		
UNIT-V	**Practical**	**30 Hours**
1. Characterization of Cu (II) coordination complexes using FT-IR, Raman, NMR, UV-Vis absorption and fluorescence spectroscopies and XRD analysis 2. Characterization of Ni (II) coordination complexes using FT-IR, Raman, NMR, UV-Vis absorption and fluorescence spectroscopies and XRD analysis 3. Characterization of organic small molecules using NMR, mass, FT-IR, UV-Vis absorption, and fluorescence spectroscopic technics		
	Total Lecture + Practical Hours	**75 Hours**
Text Books/References		

1. Straughan & Walker; For Mossbauer Effect: Aruldas and G. K. Wertheim.
2. Gunther K. Wertheim: “Mossbauer Effect: Principles and applications, (Academic Press).
3. Straughan and Walker (Eds): “Spectroscopy”- Vol. I and II (Chapman and Hall).
4. G. M. Barrow: “Introduction to molecular spectroscopy”, (McGraw Hill).
5. D. A. Long: “Raman spectroscopy” McGraw Hill (1977).
6. C. N. Banwell & E. N. McCash, Fundamentals of molecular spectroscopy, Tata, McGraw Hill.
7. Aruldhas, Molecular structure & spectroscopy, Prentice Hall, India.
8. F. W. Atkins, Physical chemistry, Oxford University Press.
9. Silverstein, Bassler, Monill – Spectroscopic identification of organic compound; John Wiley & Sons, 1991.
10. Kemp – Organic spectroscopy; McMillan, 1996.
11. R. S. Drago, Physical methods for chemists, W. B. Saunders (1992).
12. Pavia, Spectroscopy of organic compounds, Sounde Publications.
13. J. B. Lambert, H. F., Shurvell, D. A. Lightner and R. G. Cooks, Organic structured spectroscopy, Prentice Hall.
14. NMR Spectroscopy: Basic principle, concepts, and applications in chemistry by Harald Gunther; John Wiley & Sons, **2013**; ISBN: 9783527330003.
15. Modern spectroscopy by J. Mixhael Hollas; John Wiley & Sons, **2004**, ISBN: 9780470844168.
16. Vogel’s textbook of practical organic chemistry, A. R. Tatchell, John Wiley.
17. Vogel's textbook of qualitative inorganic analysis; G. Svehla and B. Sivasankar; Longman Scientific & Technical.
18. Vogel's textbook of quantitative chemical analysis; G. H. Jeffery, J Bassett, J. Mendham and R. C. Denney; Longman Scientific & Technical.

Course Code	NSP9E 601	ADVANCED ANALYTICAL TECHNIQUES	L	T	P	C
Elective			4	0	0	4
Pre-requisite	Basic knowledge in, Physical, Chemical or Biological sciences		Syllabus Version		2024	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. To familiarize and understand the fundamental principles and concepts of characterization of nanostructured materials.
2. To categorize and understand the different techniques used for studying the structural, optical, morphological, thermal, magnetic and electrochemical properties of nanomaterials.
3. To understand the working principle and instrumentation of the characterization instruments.
4. Evaluation and analysis of experimental data obtained from different instrumentation techniques

Course Outcomes

1. Recognize various characterization techniques available for the studying different properties of nanostructured materials (K1)
2. Apply the knowledge gained to correctly choose the most suitable characterization technique for studying the properties of nanomaterials (K3)
3. Effectively use the knowledge gained in analyzing the obtained characterization data. (K4, K5)
4. Evaluate the characterization data and nurture the ability to explain the underlying mechanism. (K5)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT - I	Electron Microscopy	13 Hours

Scanning Electron Microscopy (SEM): Instrumentation – Mechanism of image formation and its processing; Transmission Electron Microscopy (TEM): Instrumentation – Bright field and dark field imaging – Analysis of Micrographs – HRTEM – Selected Area Electron Diffraction

UNIT - II	Probe and Optical Microscopy	14 Hours

Atomic Force Microscopy: Instrumentation – analysis of surface roughness of thin films; Scanning Tunnelling Microscopy (STM): Instrumentation – analysis of conductivity of thin films; Near field scanning optical microscopy (NSOM); Principles of Fluorescence microscopy; Confocal Laser Scanning Microscopy

UNIT - III	Thermal, Mechanical and Magnetic Techniques	14 Hours

Thermal Analysis: TGA, DTG, DTA, DSC - combustion calorimetry – Thermal diffusivity by the laser flash technique – simultaneous techniques including analysis for gaseous products. Mechanical testing: Introduction – tension testing – High strain rate testing of

materials – Fracture Toughness testing methods – Hardness testing; Magnetic Vibrating Sample Magnetometer,		
UNIT - IV	**Structure and Surface Analysis and Electrochemical Techniques**	**14 Hours**
X-ray powder diffraction: principles and practices. Small angle X-ray diffraction, GIXRD, and Single crystalline X-ray diffraction. Hydrophobic and hydrophilic surfaces, Super hydrophobicity and hydrophilicity, Contact angle. Photoelectron spectroscopy (X-ray and Ultraviolet). BET surface area and porosity analysis; Electrochemical Techniques: Cyclic voltammetry – Electrochemical Impedance		
UNIT - V	**Contemporary Issues**	**5 Hrs**.
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**60 Hours**
Text Books/References		

1. Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, **ISBN-13:** 978-81-203-3608-7.
2. Characterization of Materials Vol 1 &2, by Elton N. Kaufmann, John Wiley and Sons Publication, 2003. New Jersey.
3. Principles of instrumental analysis, Douglas A Skoog, Donald M West, Saunders College, Philadelphia. **Publisher:** Cengage; 6 edition (1 November 2014) **ISBN-13:** 978-81-315-25579.
4. NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) **ISBN-13:** 978-0-07-061788-9
5. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander, **Publisher:** Wiley-Blackwell; 2nd Revised edition edition (1 January 1974) **ISBN-13:** 978-0471493693
6. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)**-** David B. Williams and C. Barry Carter, **Publisher:** Springer; 1st ed. 1996. Corr.6th printing edition (15 April 2005) **ISBN-13:** 978-0306453243
7. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM **-** Ray F. Egerton , **Publisher:** Springer; Softcover reprint of hardcover 1st ed. 2005 edition (12 October 2010) **ISBN-13:** 978-1441938374
8. Springer handbook of Nanotechnology ed. Bharat Bhushan (Springer), **Publisher:** Springer-Verlag (15 May 2006) **ISBN-13:** 978-3540343660.
9. Handbook of Analytical Techniques by Helmut Gunzler and Alex Williams, **Publisher**: Wiley-VCH, **2001**; ISBN: 9783527301652.
10. 2. Surface Analysis Methods in Materials Science by J. O'Connor, B. Sexton, R. Smart,**Publisher**: Springer, **2003**; ISBN: 9783540413301.
11. Modern Techniques of Surface Science by D.P. Woodruff, **Publisher**: Cambridge University Press, **2016**; ISBN: 9781139149716.

<table>
<tr><td>Course Code</td><td>NSP9E 602</td><td rowspan="2">MICRO/NANO ELECTRO-MECHANICAL SYSTEMS (MEMS/NEMS)</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Elective</td><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge in nanoscience and nanodevices</td><td colspan="2">Syllabus Version</td><td colspan="2">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
<tr><td colspan="7">Course Objectives</td></tr>
<tr><td colspan="7">1. Understand an overview of MEMS and NEMS
2. Understand different fabrication methods of MEMS/NEMS
3. Identify the applications of MEMS/NEMS
4. Understand different materials used for MEMS/NEMS</td></tr>
<tr><td colspan="7">Course Outcomes</td></tr>
<tr><td colspan="7">1. Understand the basics and working principles of MEMS/NEMS (K2)
2. Recognize different application potential of MEMS/NEMS (K2)
3. Compare the various methods of fabrication of MEMS/NEMS (K4)
4. Use MEMS and NEMS for sensing purpose (K5)</td></tr>
<tr><td colspan="7">K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create</td></tr>
<tr><td>UNIT-I</td><td colspan="3">Overview and introduction</td><td colspan="3">12 Hours</td></tr>
<tr><td colspan="7">New trends in Engineering and Science: Micro and Nanoscale systems, Overview of Nano and Microelectromechanical Systems, Introduction to Design of MEMS and NEMS, Applications of Micro and Nanoelectromechanical systems, Micro-electromechanical systems, devices and structures Definitions, Microfabrication: Introduction</td></tr>
<tr><td>UNIT-II</td><td colspan="3">Materials for MEMS and Microsystem</td><td colspan="3">12 Hours</td></tr>
<tr><td colspan="7">Introduction, Substrates and Wafers, Silicon as Substrate materials, Silicon Compounds, Silicon Piezo-resistors, Gallium Arsenide, Quartz, Piezoelectric crystals, Polymers.</td></tr>
<tr><td>UNIT-III</td><td colspan="3">Fundamentals of MEMS Fabrication</td><td colspan="3">12 Hours</td></tr>
<tr><td colspan="7">Introduction, Photolithography, ion implantation, Diffusion, Oxidation, Chemical vapor deposition, sputtering, Deposition by Epitaxy, Etching, MEMS fabrication technologies-bulk micromachining, Surface micromachining, High-aspect-ratio (LIGA and LIGA-Like) technology</td></tr>
<tr><td>UNIT-IV</td><td colspan="3">Working Principles of microsystems</td><td colspan="3">14 Hours</td></tr>
<tr><td colspan="7">Introduction, Microsensors - Acoustic wave sensors, Biomedical and biosensors, chemical sensors, optical sensors, pressure sensors, thermal sensors, Microactuation-Actuation using thermal forces, piezoelectric effect, electrostatic effect. MEMS with microactuators-microgrippers, miniature microphones, micromotors.</td></tr>
<tr><td>UNIT-V</td><td colspan="3">Microsystem Design</td><td colspan="3">10 Hrs.</td></tr>
<tr><td colspan="7">Design considerations-materials, manufacturing processes, Signal transduction, Process design-Photolithography, Thin-film fabrication, Geometry shaping, Mechanical design.</td></tr>
</table>

		Total Lecture Hours	**60 Hours**
Text Books/References			

1. Tai-Ran Hsu, MEMS and Microsystems- Design, Manufacture and Nanoscale Engineering, John Wiley & Sons, INC. 2008. **ISBN:** 978-0-470-08301-7.
2. MEMS and NEMS: Systems, Devices, and Structures Sergey Edward Lyshevski . CRC PRESS ISBN: 0-8493-1262-0
3. Mohamed Gad – el – Hak, “The MEMS Handbook”, Second Edition, CRC Press, 2005.
4. James J. Allen, “Micro Electro Mechanical System Design”, CRC, 2005.
5. K. Subramanian, “Micro Electro Mechanical Systems: A Design Approach”, Springer, 2008.

<table>
<tr><td>Course Code</td><td>NSP9E 603</td><td rowspan="2">COMPUTATIONAL NANOTECHNOLOGY</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Elective</td><td>3</td><td>0</td><td>1</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge in general physics, Chemistry and mathematics.</td><td>Syllabus Version</td><td colspan="3">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
<tr><td colspan="7">Course Objectives</td></tr>
<tr><td colspan="7">The main objectives of the course are to:
• Understand different computational tools.
• Learn to write z-matrix for simple systems.
• Understand different kinds of modelling and simulations.
• Evaluate different computed results through various methods.</td></tr>
<tr><td colspan="7">Course Outcomes</td></tr>
<tr><td colspan="7">1. Introduction to different computational tools – K2
2. Understand the need and importance of computational studies in supporting scientific results – K3, K4
3. Learn to write inputs for computational calculations – K2, K3, K6
4. Understand different simulations and applications by using through software – K3, K5, K6</td></tr>
<tr><td colspan="7">K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create</td></tr>
<tr><td>UNIT-I</td><td colspan="3">Basic principles</td><td colspan="3">9 Hours</td></tr>
<tr><td colspan="7">Potential energy scanning, saddle points, Stable conformer-local and global minima. Geometry optimization, Molecular orbital, charges, electron density. RA approximation. Van der waal’s corrections. Frequency calculation. Interaction energy. ESP map. Solvent Continuum models. Fock matrices.</td></tr>
<tr><td>UNIT-II</td><td colspan="3">Computational Methods and Basis sets</td><td colspan="3">12 Hours</td></tr>
<tr><td colspan="7">Basis sets- different types: Basis set truncation error. Correlation energy. Basis set limit. Slater type orbitals and Gaussian type orbitals; z-matrix- basic idea and construction. General classification- Classical and quantum mechanical. Molecular mechanics. Semi-Empirical method. Ab initio method. Density functional theory method. Molecular dynamics. ONIOM method. Simulations.</td></tr>
<tr><td>UNIT-III</td><td colspan="3">Computational Analysis</td><td colspan="3">12 Hours</td></tr>
<tr><td colspan="7">Z-matrix of small molecules like H_2O, HCHO, CH_3OH and H_2O_2. Global reactive descriptors. Fukui descriptors. QSAR/QSPR study; TDDFT. Analysis of MOs; NBO analysis. Thermal properties. Marcus theory (Detailed analysis). Restricted and unrestricted analysis.</td></tr>
<tr><td>UNIT - IV</td><td colspan="3">Computational Nanotechnology</td><td colspan="3">12 Hours</td></tr>
<tr><td colspan="7">Quantum confinement; change in properties with size. Applications of computational studies in nanotechnology. Simulations-different types-Monte Carlo Methods. Nano-</td></tr>
</table>

computing and modelling. Computing transport in materials. Nanodesign-Nano-CAD. Nanomedicine (brief study only)		
UNIT-V	**Computational Lab - III**	**30 Hrs**.
• PES and geometry optimizations of large molecules • Spectroscopic analysis of compounds • Thermochemical analysis • Correlation study - Statistical analysis • 2D-QSAR modelling • Monte Carlo Simulation • BDE calculation • pKa calculation		
	Total Lecture + Practical Hours	**75 Hours**
Text Books/References		

1. D. Frenkel and B. Smith, ―Understanding molecular simulation from algorithm to applications‖, Kluwar Academic Press, 1999.
2. K. Ohno, K. Esfarjani and Y. Kawazoe, ―Introduction to Computational Materials Science from ab initio to Monte Carlo Methods‖, Springer-Verlag, 1999.
3. Jenson F, Introduction to Computational Chemistry – John Wiley
4. Cramer C.J., Essentials of Computational Chemistry – John Wiley
5. Young, Computational Chemistry – Wiley Inter Science
6. Andrews R. Leach, Molecular Modeling – Pearson
7. Ramachandran K.I et al computational Chemistry and Molecular Modeling Springer.
8. Schlick. T., Molecular Modeling and Simulations, Springer.
9. Python for Education, Ajith Kumar B.P. IUAC, New Delhi; free e-book.
10. Introduction to Python for Engineers and Scientists by Dr.Sandeep Nagar, Apress publications

<table>
<tr><td>Course Code</td><td>NSP9E 604</td><td rowspan="2">DESIGN, SYNTHESIS AND PROPERTIES OF NANOMATERIALS</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Elective</td><td>3</td><td>0</td><td>1</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge in physics, chemistry and nanoscience</td><td colspan="2">Syllabus Version</td><td colspan="2">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
</table>

Course Objectives

The main objectives of the course are to:

1. Understand different top-down and bottom-up approaches available for nanomaterials synthesis.
2. Apply the knowledge on synthesis to properly design an experiment for tuning the size, shape and properties of the nanostructures
3. Understand and apply different lithographic techniques for the fabrication of nanostructures
4. Understand the fundamental principles and concepts related to the optical, electrical, magnetic, thermal and mechanical properties

Course Outcomes

1. Understand physical, chemical, and lithographic techniques available for the preparation of nanoparticles or nanostructures and apply the knowledge to select a proper synthetic approach for a specific application (K2. K5)
2. Create experimental design to control the size, shape, distribution and properties of nanoparticles (K6)
3. Apply and analyze the design criteria for the fabrication of nanostructures by lithography (K3,K4)
4. Evaluate and correlate the structure-property optimization using the data collected from different analysis (K5,K6)
5. Apply the size and shape dependence of materials properties for tuning the material for various applications (K3)
6. Review the advantages of using nanostructured materials for various applications and the challenges that will face while using nanomaterials (K5)

K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6- Create

UNIT-I	**Physical and Chemical Methods**	**15 Hours**

Physical Vapour deposition techniques (PVD): Sputtering & e-beam Evaporation. Atomic layer deposition, Chemical vapour deposition method (CVD), Molecular beam epitaxy(MBE), & Electrospinning, Ball Milling. Chemical Methods: Nanoparticles through homogeneous &heterogenous nucleation in solution:-Co-precipitation method, Hydrothermal/ Solvothermal synthesis, Template based synthesis, Electrochemical synthesis, Sonochemical routes, Sol- gel, Micelles and microemulsions. Self-assembly methods and Langmuir Blodgett (LB) method.

UNIT-II	**Lithographic Techniques**	**10 hours**

Lithography- Photolithography- Laser lithography and SPM based lithography (AFM & STM), Dip pen lithography and nanomanipulation. E-beam/SEM lithography. X-ray Lithography, Focused Ion beam lithography.

UNIT-III	Optical Properties of Nanostructures	10 Hours

Interaction of light with matter. The nano perspective. The surface plasmon resonance- applications of nano plasmonics. Quantum dots – Optical properties related to quantum confinement. Special luminescent materials - electroluminescence- photochromic and electrochromic nanomaterials.

UNIT-IV	Electrical properties of Nanostructures	10 Hours

Electrical conductivity in one dimensional nanostructure (CNTs). Electronic transport in nanostructures, single electron transfer devices (SETs). Molecular electronics: transport properties of molecular wires. Molecular devices.

UNIT-V	Practical Experiments	30 Hrs.

1. Chemical synthesis of CdSe Quantum dots with five different sizes.
2. Band gap determination and size estimation of CdSe quantum dots by using optical spectroscopy
3. Emission behaviour of CdSe QDs by using Spectrofluorometer
4. Chemical Synthesis of Two different magnetic nanoparticles and size determination from XRD.
5. Metal chalcogenide film with different thickness via SILAR method and thickness measurements by profilometer
6. Wet chemical synthesis of ZnO nanoparticles and optical studies using UV-Vis Spectroscopy
7. Au nano rod preparation and record the SPR spectrum using UV-Vis Spectroscopy
8. Polyaniline synthesis and study the chemical structure using FTIR spectroscopy

	Total Lecture Hours	75 Hours

Text Books/References

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by GuozhongCao , Imperial college Press, (2006).**Publisher:** World Scientific Publishing Company; 2 edition (4 January 2011) **ISBN-13:** 978-9814324557
2. An introduction to Electrospinning and Nanofibers by Seeram Ramakrishna, KazutoshiFujihara, Wee Eong Tee, Teck Cheng Lim, Zaveri Ma, World Sci. Pub. Ltd. Singapore, 2005, **Publisher:** World Scientific Publishing Co Pte Ltd (8 May 2005) **ISBN-13:** 978-9812564542
3. Springer Handbook of Nanotechnology - Bharat Bhusan, **Publisher:** Springer-Verlag (15 May 2006) **ISBN-13:** 978-3540343660
4. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. **Publisher:** CRC Press (15 December 2008) **ISBN-13:** 978-1420047790
5. Introduction to Nanoscale Science & Technology, Di Ventra, Evoy, Heflin, Springer Science, NY, 2004, **Publisher:** Springer; 1 edition (30 June 2004)
   Sold by: Amazon Asia-Pacific Holdings Private Limited

6. Nanofabrication- Fundamentals and Applications, By Ampere A Tseng, World Scientific, Singapore 2008. **Publisher:** World Scientific Publishing Co Pte Ltd (18 March 2008) **ISBN-13:** 978-9812705426
7. Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim (Federal Republic of Germany), 1998, **Publisher:** Wiley VCH (28 May 1998) **ISBN-13:** 978-3527294435

8. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens, **Publisher:** Wiley-Interscience; 1 edition (30 May 2003) **Sold by:** Amazon Asia-Pacific Holdings Private Limited.
9. Nanomaterials – An Introduction to synthesis, Properties and Applications, by Dieter Vollath, Wiley – VCH Verlag GmbH & Co. Germany, 2008.
10. Properties of nanomaterials by Charles P. Poole.
11. The Physics & Chemistry of Nanosolids by Frank J. Owens and Charles P. Poole Jr. , John Wiley & Sons, Inc. New Jersey 2008.

1. Introduction to Nanoelectronics, by V. Mitin, V. Kochelap, M. Stroscio, **Cambridge University Press (2008).**
2. Nanoelectronics and Photonics: From Atoms to Materials, Devices,and Architectures by Anatoli Korkin l Federico Rosei, **2008 Springer Science, Business Media, LLC.**
3. Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices, by Rainer Waser, **Wiley-VCH (2003).**
4. Nanoelectronics and Nanosystems, by Karl Goser, Peter Glosekotter, Jan Dienstuhl, **Springer (2004**).
5. Nanotechnology & Nanoelectronics, Materials, devices, measurement techniques, by W. R. Fahrner(Editor), **Springer, 2005**
6. Principles of Nanophotonics, by MotoichiOhtsu, Kiyoshi Kobayashi, Tadashi Kawazoe,TakashiYatsui,MakotoNaruse**, CRC press 2008 by Taylor & Francis Group**
7. Semiconductor Quantum Dots, L. Banyai and S.W.Koch, **World Scientific (1993).**
8. NanoBiophotoics, H. Masuhara, S. Kawata and F. Tokunga, **Elsevier Science, (2007).**
9. Fundamentals of Photonics, B. E. A. Saleh and A. C. Teich, John Wiley and Sons, NewYork, (1993).
10. Introduction to Biophotonics, P. N. Prasad **John Wiley and Sons, (2003).**
11. Molecular Nanomagnets, Dante Gatteschi, Roberta Sessoli, Jacques Villain, Oxford **University Press 2006, USA.**
12. Concepts in Spin Electronics, Sadamichi Maekawa, **Oxford University Press (2006).**
13. Nanomagnetism and Spintronics: Fabrication, Materials, Characterization and Applications
14. Farzad Nasirpouri , Alain Nogaret **Publisher:** World Scientific Publishing Company;
edition (December 21, 2010) **ISBN-10:** 9814273058
15. Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Edward L. **Wolf Wiley-VCH (2006).**

<table>
<tr><td>Course Code</td><td>NSP10P 601</td><td rowspan="2">PROJECT</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Project</td><td>0</td><td>0</td><td>20</td><td>20</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge on nanoscience and nanomaterials</td><td colspan="2">Syllabus Version</td><td colspan="2">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
<tr><td colspan="7">Course Objectives</td></tr>
<tr><td colspan="7">1. Inculcate and improve the research attitude of the student
2. To understand the process of literature review and use of online research resources
3. Train to design a research problem and to understand how to fix the objectives and methodologies to solve the problem
4. Documentation practices and improvement of communication and presentation skills</td></tr>
<tr><td colspan="7">Course Outcomes</td></tr>
<tr><td colspan="7">1. Apply the scientific concepts to identify and design a research problem in the area of nanoscience (K3)
2. Understand and analyze the results or data obtained from experiments or simulation using data analysis softwares (K2,K4)
3. Apply the theoretical knowledge to explain the data collected from different advanced characterization techniques (K3)
4. Understand the importance of documentation procedure and research publication. (K2)</td></tr>
<tr><td colspan="7">K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create</td></tr>
<tr><td></td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="7"></td></tr>
</table>

NSP10M 601 MOOC III ONLINE Course - 4 Credits

Course Code	NSP10C 604	BIO-NANOMATERIALS	L	T	P	C
Core Course			4	0	0	4
Pre-requisite	Basic knowledge in physical, chemical and biological sciences		Syllabus Version	2024		

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. To understand the applications of various nanomaterials in biology
2. To analyze the potentials of nanoprobes
3. To evaluate the uses of different nanoprobes
4. To create new functional nanoprobes for advanced applications

Course Outcomes

1. This course is designed to understand (K1) the applications of different nanomaterials in biology.
2. The detailed description of this particular course module will help students to analyze (K2) each nanomaterials' uses at the laboratory level.
3. Towards the end of this course, students could evaluate (K3) which nanoprobes will be ideal for specific applications.
4. Such experience will help to create (K4) novel materials during their Ph.D. career.

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Nanomaterials for Bio-labeling and Bio-imaging	16 Hours

Different methods for bio-labeling, bio-conjugate chemistry, and variety of nanoprobes (carbon nanomaterials, semiconductor quantum dots, metal nanoclusters, polymer nanoparticles, up conversion nanoparticles, plasmonic nanoparticles), etc. Raman imaging, fluorescence imaging, magnetic resonance imaging, positron emission tomography, photoacoustic imaging, ultrasound imaging, X-ray computed tomography, etc.

UNIT-II	Nanomaterials for Delivery and Therapeutics	13 Hours

Different techniques to deliver drugs, gene, mRNA, etc. Photothermal therapy, photodynamic therapy, chemotherapeutics, etc.

UNIT-III	Nanomaterials for Tissue Engineering	14 Hours

Introduction, Artificial implants, scaffolds used for tissue engineering based on nanomaterials – bones, skin and neurons.

UNIT-IV	Nanomaterials for bioelectronics	12 Hours

Nanoparticle-biomaterial hybrid systems for bioelectronic devices, nanoparticle-enzyme hybrids; bio-recognition. Biomaterial based metallic nanowires, networks and circuitry. DNA as functional template for nanocircuitry; Protein based nanocircuitry.		
UNIT-V	**Contemporary Issues**	**5 Hrs**.
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**60 Hours**
Text Books/References		

1. Nanomaterials and Their Applications in Bio-imaging (Plant nanobiotics) by Prasad, R. **Publisher**: Springer, **2019**, ISBN: 9783030164386.
2. Carbon Nanomaterials for Bio-imaging, Bio-analysis, and Therapy in Nanocarbon Chemistry and Interfaces by Hui, Y. Y.; Chang, H.-C.; Dong, H.; Zhang, X. **Publisher**: John Wiley & Sons, **2018**, ISBN: 978-1119373452.
3. Nanotechnology for Biomedical Imaging and Diagnostics: From Nanoparticle Design to Clinical Applications by Berezin, M. Y. **Publisher**: John Wiley & Sons, **2014**, ISBN: 9781118121184.
4. Nanofabrication towards biomedical application: Techniques, tools, Application and impact by Challa S., Kumar, S. R.; Carola. **Publisher**: J. H. John Wiley & Sons, **2005**; ISBN: 9783527311156.
5. Tissue Engineering, Palsson, B. O.; Bhatia, S. N. Publisher: Prentice Hall, 2003; ISBN:
6. Lanza, R.; Langer, R.; Joseph, P. Principles of Tissue Engineering. **Publisher**: Academic Press. **2013**; ISBN-10: 0130416967.
7. Nanobioelectronics for Electronics, Biology, and Medicine by Offenhäusser, Andreas, Rinaldi, Ross, **Publisher**: Springer, **2009**; ISBN: 9781441918574.

Course Code	NSP10C 605	ADVANCED NANOMATERIALS	L	T	P	C
Core Course			4	0	0	4
Pre-requisite	Basic Knowledge in Nanoscience and Nanomaterials		Syllabus Version	2024		

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. To understand the importance of advanced nanostructured materials and their properties.
2. To understand the concepts of functionalization of carbon nanotubes and analyze the change in the physical and chemical properties.
3. To understand the properties of micro and mesoporous materials and their applications.
4. To understand the properties of ultrahard smart materials and nanocomposites.

Course Outcomes

1. To remember the various type of advanced nanostructured materials that could be utilized for various applications.(K1)
2. To apply the concepts of functionalization while designing CNT composites for a specific application. (K3)
3. To apply the knowledge gained while designing novel nanocomposites.(K3)
4. To nurture the ability of critical thinking towards the design and development nanostructured materials for a specific application.(K6)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Carbon Nanostructures	14 Hours

Introduction:- Diamond – Graphite- Fullerenes, CNTs and Graphene. Synthesis: CVD, Laser and Electrochemical and other methods. Functionalization and reactivity of CNTs, Covalent Functionalization -Oxidative Purification, Defect Functionalization –Sidewall Functionlaization, Noncovalent Exohedral Functionalization, Endohedral Functionalization.

UNIT-II	Special Nanomaterials	14 Hours

Micro & Mesoporous Materials **-** Ordered mesoporous structures, Random mesoporous structures, and crystalline microporous materials: zeolites. Core – Shell Structures **-** Metal-oxide structures, Metal-polymer structures, Oxide-polymer structures. Organic-Inorganic Hybrids- Class I hybrids, Class I1 hybrids, Intercalation Compounds.

UNIT-III	Ultra Hard Smart Materials	14 Hours

Introduction- synthesis properties and applications of ultra nanocrystalline diamond-growth,electronic properties and application of nanodimond. Dimond like materials- CNTS and Nitrides, C_3N_4-Boron nitride etc.

UNIT-IV	Nanocomposites	14 Hours
Introduction to Nanocomposites – Layered Silicates-Polyamide-clay nanocomposites. Epoxy nanocomposites based on layered silicates and other nanostructured fillers. Biodegradable polymer silicate nanocomposites. Metal Polymer Nanocomposites-synthesis- Ex-situ and in-situ approaches-Optically anisotropic metal –polymer nanocomposites. Conducting nanocomposite systems- Introduction, classification and host guest materials for nanocomposite systems.		
UNIT-V	**Contemporary Issues**	**4 Hrs**.
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**60 Hours**
Text Books/References		

1. Carbon Materials & Nanotechnology, By Anke Krueger, Wiley VCH Verlag **GmbH & Co. KGaA, 2010, Weinhein.**
2. Dimond Nanotechnology- Synthesis and Applications, by James Sung, Pan **Stanford Publishing (July 31, 2009)**
3. Nanostructures and Nanomaterials - Synthesis, Properties and Applications - Cao, Guozhong, **Imperial college press, 2004.**
4. Polymer nanocomposites, Edited by Yiu-Wing Mai and Zhong-Zhen Yu, **CRC Press, Woodhead Publishing Limited, 2006.**
5. The New Frontiers of Organic and Composite Nanotechnology, Victor Erokhin, Manoj Kumar **Ram and Ozlem Yavuz, 2008 Elsevier Ltd.**
6. Metal – Polymer nanocomposites by Luigi Nicolais and Gianfranco Carotenuto, **John Wiley & Sons, Inc. 2005.**
7. Nanoscale materials -Liz Marzan and Kamat **Publisher:** Wiley; 2 edition (2009)
8. Synthesis functionalization and surface treatment of nanoparticles - Marie Isabelle Baraton
9. Physical properties of Carbon Nanotube-R Satio **Publisher:** Am. Sci. Publishers (2002)
10. Applied Physics Of Carbon Nanotubes : Fundamentals Of Theory, Optics And Transport devices , S. Subramony & S.V. Rotkins **Publisher:** Springer; 2005 edition.
11. Carbon Nanotubes: Properties and Applications**-** Michael J. O'Connell **Publisher:** CRC Press; edition (2006)
12. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing **Publisher:** Royal Society of Chemistry.
13. Nanosilicon by Vijay Kumar, Elsevier Ltd. UK ,2007. **Publisher:** Elsevier Science (2014)

Course Code	NSP10C 606	NANOSTRUCTURED SUPERCAPACITORS	L	T	P	C
Core Course			4	0	0	4
Pre-requisite	Basic knowledge in Nanoscience		Syllabus Version	2024		

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Conscious of energy crisis, its reason, current status and possible solutions
2. Recognize the significance of energy storage
3. Importance of efficient storage and release of energy
4. Role of Nanoscience or nanotechnology in producing novel materials and designs for efficient storage of energy using renewable resources

Course Outcomes

1. Analyze the performance of electric capacitors and understand their advantages and disadvantages (K4, K2)
2. Understand different electrochemical techniques to know better the electrode-electrolyte interface (K2)
3. Understand the possibilities of electrochemical double layer supercapacitors for efficient energy storage and create awareness on using such advanced technologies (K2, K6)
4. Analyze the importance of novel energy storage devices with improved performance using nanoscience (K4)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Fundamentals of Electric Capacitors	13 Hours

Introduction, energy storage in capacitor, types and structures of capacitors. General principles of electrochemistry, equilibrium electrochemistry, dynamic electrochemistry. General properties of electrochemical capacitors. Electrochemical cell, electrochemical interfaces, different electrochemical techniques.

UNIT-II	Electrochemical Double-Layer Supercapacitors	14 Hours

Introduction, Electrode-Electrolyte interfaces, Electrode Potential and double layer potential windows. Electrochemical double layer supercapacitors: structure and capacitance, equivalent series resistance, leakage resistance, supercapacitor charging and discharging, energy and power densities of EDL supercapacitors. EDLC electrode Materials.

UNIT-III	Electrochemical Pseudo capacitors	14 Hours

Introduction, Electrochemical pseudo capacitors, interfaces of electrode and electrolyte. Electrochemical Impedance spectroscopy and equivalent circuits. Electrode materials and Cell Designs. Pseudo capacitive materials, Asymetric structures. Electrolyte structures and materials.

UNIT-IV	Characterization & Applications of Electrochemical Supercapacitors	14 Hours

Electrochemical cell design and fabrication. Cyclic voltammetry, Charging Discharging curve, electrochemical impedance spectroscopy, Physical Characterization methods. Applications of Electrochemical supercapacitors: power electronics, portable energy systems, hybrid electric vehicle etc. Perspectives and challenges of electrochemical super capacitors		
UNIT-V	**Contemporary Issues**	**5 Hrs**.
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**60 Hours**
Text Books/References		
10. Electrochemical Supercapacitors for Energy Storage and Delivery: Fundamentals and Applications, by Aiping Yu, Victor Chabot and Jiujun Zhang, CRC Press, Tylor & Francis Group, New York (2013). 11. Supercapacitors: Materials, Systems and Applications, Max Lu, Francois Beguin, Elzbieta Frackowiak,		

<table>
<tr><td>Course Code</td><td>NSP10C 607</td><td rowspan="2">NANOMATERIALS FOR SUSTAINABLE TECHNOLOGY</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Core Course</td><td>3</td><td>0</td><td>1</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge in nanomaterials and their synthesis</td><td>Syllabus Version</td><td colspan="3">2024</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
</table>

Course Objectives

1. Familiarize students the importance of nanomaterials for sustainable development.
2. Enhancing the student's knowledge on nanomaterials for environmental remediation.
3. Understand the photocatalysis reactions for solar fuel generation.
4. Apply the knowledge gained for developing efficient nanostructured photocatalysts.

Course Outcomes

1. Understand the benefits of nanomaterials for sustainable development (K2)
2. Analyze the concepts of photocatalysis and its technological significance. (K4)
3. Apply the photocatalysis reaction mechanisms towards contaminant degradation, hydrogen evolution and carbon dioxide reduction. (K3)
4. Create strategies for developing efficient nanostructured photocatalysts.(K6)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Photocatalysis**	**13 Hours**

Introduction; Light and matter interaction; Principles of Photocatalysis; Electronic band structure of semiconductors; Mechanisms of charge formation, separation and transfer; Basic principles of photocatalytic water splitting for hydrogen generation; Basic principles of photocatalytic reduction of CO_2; Photocatalysis surface and active species.

UNIT-II	**Environmental Remediation**	**14 Hours**

Introduction; Fabrication of nanostructured photocatalysts; Methods of improving photocatalytic activity: Design parameters; Photodegradation of dyes; Photodegradation of persistent organic pollutants; Photodegradation of Inorganic pollutants; Photodegradation of emerging contaminants; Photodegradation of gaseous pollutants; Characterization and analysis of acquired data.

UNIT-III	**Hydrogen Evolution and Carbondioxide Reduction**	**14 Hours**

Introduction; Electronic band structure considerations; Photocatalytic reaction mechanism and charge transfer; Fabrication of nanostructured photocatalysts and design parameters: H_2 generation and CO_2 reduction; Z-scheme heterojunction photocatalysts; Quantification and calculation of efficiency; Characterization

UNIT-IV	**Strategies for Improving Performance of Photocatalysts**	**14 Hours**
Introduction; Issues related to single-component photocatalysts; Microstructure modulation; Influence of facet and defects; Integration of noble metal nanostructures; Carbonaceous materials compounding – rGO, CNTs, CQDs; Integration with other semiconductor nanostructures.		
UNIT-V	**Contemporary Issues**	**5 Hrs**.
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**60 Hours**
Text Books/References		

1. Gianluca Li Puma, Detlef W. Bahnemann, Dionysios D. Dionysiou, Jinhua Ye and Jenny Schneider, Photocatalysis: Fundamentals and Perspectives, Publisher: Royal Society of Chemistry, ISBN: 9781782620419, 1782620419.
2. Umar Ibrahim Gaya, Heterogeneous Photocatalysis Using Inorganic Semiconductor Solids, Publisher: Springer Netherlands, ISBN: 9789400777750, 9400777752
3. Kazuya Nakata and Akira Fujishima, TiO_2 photocatalysis: Design and applications, Journal of Photochemistry and Photobiology C: Photochemistry Reviews 2012, 13, 169-189, https://doi.org/10.1016/j.jphotochemrev.2012.06.001
4. Chunping Xu, Prasaanth Ravi Anusuyadevi, Cyril Aymonier, Rafael Luque and Samuel Marre, Nanostructured materials for photocatalysis, Chemical Society Reviews, 2019,48, 3868-3902, https://doi.org/10.1039/C9CS00102F

Course Code	NSP10C 608	COMPUTATIONAL STUDIES ON BIO-ACTIVE COMPOUNDS	L	T	P	C
Core Course			4	0	0	4
Pre-requisite	Basic knowledge in general Chemistry and mathematics.		**Syllabus Version**		**2024**	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

The main objectives of the course are to:

- Understand different statistical tools in data analysis.
- Learn different bio-active compounds.
- Learn the pathway for drug discovery.
- Employ different computational tools to evaluate different bio-active compounds.

Course Outcomes

1. Understand different tools for data analysis – K3, K4, K5
2. Understand the need and importance of computational studies in supporting scientific results – K1, K4
3. Learn drug likeness and related parameters for drug discovery – K2, K3, K6
4. Understand different computational tools for evaluating drug-target interactions– K3, K4, K5

K2 – Understand K3 – Apply K4 – Analyze K6 - Create

UNIT-I	Errors and Statistical Tools in Data Analysis	12 Hours

Significant figures. Errors and classification; accuracy and precision; significant figures and rules; selection of data- T-test; F-test; Q-test; Euler's theorem- exact and inexact differentials.

UNIT-II	Bio-active Compounds & Metals in Medicine	12 hours

Bio-active compounds: Structure and general characteristics. Medicinal importance of bio-active compounds. Bio-activities. ED50, IC50, TD50 and LD50. Metal toxicity and homeostasis. Metal deficiency and diseases. Toxicity due to non-essential elements. Chelation therapy and chemotherapy. Metal complexes as drugs (brief only).

UNIT-III	Medicinal Chemistry I	12 Hours

Features of Drug like molecules. Drug classification: synthetic, semi-synthetic and nonsynthetic drugs. Drug classification according to medicinal use: pharmacodynamic medicinal use. Pharmacodynamic agents and chemotherapeutic agents. Lipinski's rule of 5. Physicochemical properties determining biological activity such as solubility, acidity and reactivity. Importance of liphophilicity constant (logP).

UNIT-IV	Medicinal chemistry II	12 Hours

Isosterism and bioisosterism. A brief introduction on the following terms: Pharmacology, Pharmacodynamics, Pharmacokinetics and ADME, pharmacotherapeutics, pharmacogency, toxicology, Basic steps in drug discovery: from lead discovery to commercialization (a brief introduction only).

UNIT-V	Computation of Bio-active Compounds	12 Hrs.
Combinatorial chemistry. QSAR/QSPR study. Molecular docking. Donar-acceptor interactions. Different biological assays (brief idea only). Experimental versus computational studies. UV filtering and metal chelation capacity. Multi target interactions. Molecular simulations		
	Total Lecture Hours	**60 Hours**
Text Books/References		

1. D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8th Edn., Saunders College Pub., 2007.
2. Jenson F, Introduction to Computational Chemistry – John Wiley
3. Cramer C.J., Essentials of Computational Chemistry – John Wiley
4. Young, Computational Chemistry – Wiley Inter Science
5. S.S. Sastry (SS), Introductory Methods of Numerical Analysis, PHI
6. J.B.Scarborough (SB), Numerical Mathematical Analysis, Oxford & IBH
7. Wilson and Gisvold's Textbook of Organic Medicinal and Pharmaceutical Ch emistry. Author(s): John M Beale Jr., PhD , John Block , ISBN/ISSN: 9780781779296, Edition: Twel fth, 2010
8. Gareth Thomas, Fundamentals of Medicinal Chemistry, ISBN: 9780470 84307-9, WileyBlackwell